

Applied Crowd Science

Essays and Case Studies

Edited by

G. Keith Still BSC PHD FIMA FICPEM FIPM FHEA MEA

CONTENTS

Acknowledgements	7
Essays on crowd science	8
Catastrophe theory	8
Student papers	9
Breda University of Applied Science	9
History of BUAS and event safety and logistics	9
Development of the minor	11
Crowd safety and COVID-19	12
Design and focus of research	13
Collecting data	13
Research findings	14
References	15
Crowd science essays	15
Manon Gijbels – Event safety planning	16
About Manon	16
Crowd science essay	16
References	21
Íse Murphy – introduction to crowd science and Risk Analysis	25
<i>About Íse</i>	25
<i>Introduction</i>	25
<i>Crowd science</i>	26
<i>Concepts of crowd science</i>	27
<i>Legal framework</i>	27
<i>Crowd risk analysis</i>	27
<i>Conclusion</i>	28
References	29
Aldo Raineri – crowd safety and crowd risk analysis	30
<i>About Aldo</i>	30
<i>Introduction</i>	30
<i>What is crowd science?</i>	31
<i>Key elements of, and theories underpinning, crowd science</i>	31

<i>The legal, regulatory and risk management framework</i>	32
<i>Why is there a need for a crowd science approach?</i>	33
<i>Crowd risk analysis</i>	33
<i>A framework for crowd risk analysis</i>	33
<i>Methods and tools for crowd risk analysis</i>	34
<i>Conclusion</i>	34
References	34
Kristin Finn – an analysis of crowds for event safety	36
<i>About Kristin</i>	36
<i>Introduction</i>	36
References	42
Tristan Taylor – crowd safety and risk analysis in Australia	44
<i>About Tristan</i>	44
<i>Introduction</i>	44
<i>Law</i>	44
<i>Guidelines</i>	45
<i>History and lessons learnt</i>	45
<i>Risk analysis</i>	46
<i>Risk management</i>	46
<i>Reactive plans vs proactive plans</i>	47
References	47
Marc Tubee – crowd science in Holland	49
<i>About Marc</i>	49
<i>What is crowd science</i>	50
<i>Risk assessment methodology</i>	51
Sheila Russell – defining crowd science	55
<i>About Sheila</i>	55
<i>Introduction</i>	55
References	59
Andrew Seeds – crowd science	60
<i>About Andrew</i>	60
<i>Introduction</i>	60
<i>Key theories</i>	61
<i>Fruin – level of service</i>	61
<i>Fruin – causes and prevention of crowd disasters</i>	61
<i>Fruin – crowd dynamics</i>	61
<i>Convergence theory</i>	61
<i>De-individualisation theory</i>	61
<i>Legal framework</i>	62
<i>Integration of crowd science within the licensing/permitting process</i>	62
<i>Event planning</i>	63
<i>Event delivery</i>	64
<i>Risk Assessment methodologies (and their application to crowd safety)</i>	64
References	65

Shane Harris – crowd science – Australia	67
<i>About Shane</i>	67
<i>Introduction</i>	67
<i>Crowd density</i>	67
<i>Crowd behaviour</i>	68
<i>Crowd dynamics</i>	68
<i>Regulatory requirements</i>	69
<i>Building compliance</i>	69
<i>Risk assessments</i>	70
<i>Simulations and models</i>	70
References	71
Eric Kant – introduction to crowd science	74
<i>About Eric</i>	74
<i>Introduction</i>	74
<i>Crowd science</i>	74
<i>Key theories that underpin crowd science</i>	75
<i>Risk assessment</i>	75
<i>Conventional risk assessment process</i>	75
<i>Appropriate risk assessment methodology</i>	76
<i>Influences on crowd behaviour</i>	77
<i>Phases of crowd behaviour</i>	77
<i>Modes of crowd behaviour</i>	78
<i>DIM-ICE matrix</i>	78
<i>Legal, regulatory and risk management framework</i>	78
<i>Crowd science and its application within the events scenario</i>	79
References	80
Graeme Clark – crowd safety and risk analysis	81
<i>About Graeme</i>	81
<i>Essay – introduction</i>	81
<i>What is crowd science?</i>	82
<i>Risk analysis and crowd safety</i>	83
<i>Risk analysis – a traditional approach</i>	84
<i>Risk analysis – a crowd science approach</i>	84
<i>Conclusion</i>	85
References	85
Kevin Kennedy – crowd science in Canada	87
<i>About Kevin</i>	87
<i>Introduction</i>	88
<i>Definition: what is crowd science?</i>	88
<i>Key theories</i>	88
<i>Proxemics</i>	88
<i>Crowd density as it relates to crowd dynamics</i>	89
<i>Crowd behaviour</i>	89
<i>Social identity approach</i>	89
<i>Legal issues</i>	89
<i>How it can be incorporated into event planning?</i>	90

<i>Planning and communications</i>	90
<i>Tools</i>	91
<i>Conclusion</i>	91
References	92
Ryoki Murayama – crowd science and simulation	93
<i>About Ryoki</i>	93
<i>Crowd science</i>	93
<i>Self-driven particle</i>	93
<i>Pedestrian movement</i>	93
<i>Crowd dynamics</i>	94
<i>Crowd accident</i>	94
<i>Crowd density and human pressure</i>	95
<i>Crowd behaviour</i>	95
<i>Crowd density and walking speed</i>	96
<i>Normal times and stress times</i>	96
<i>Crowd risk analysis</i>	96
<i>Event tree analysis</i>	97
<i>Risk matrix</i>	97
<i>Conclusion</i>	97
References	97
Crowd science case studies	99
Kristin Finn – Rugby World Cup, Fan Zone	100
<i>Introduction</i>	100
<i>Analysis of Rugby Fan Zone site, Exeter</i>	100
<i>RAMP analysis – routes (directions)</i>	101
<i>Areas</i>	101
<i>Movement</i>	102
<i>Profile</i>	103
<i>DIM-ICE evaluation</i>	104
<i>Congestion/Risk maps for the site</i>	104
<i>Decision support matrix/analysis</i>	104
<i>Conclusion and recommendations</i>	105
References	108
Manon Gijbels – Dordrecht, analysis of the weekly market	112
<i>About Manon</i>	112
<i>Introduction</i>	112
<i>RAMP analysis</i>	113
<i>DIM-ICE risk modelling</i>	117
<i>Risk mapping</i>	119
<i>Decision support analysis</i>	120
<i>Conclusion</i>	121
References	122
Bert Bruyninckx – bicentenary of the battle of Waterloo	126
<i>About Bert</i>	126
<i>Introduction to the event</i>	126
<i>RAMP analysis</i>	126

<i>DIM-ICE – normal</i>	130
<i>Results of the DIM-ICE and RAMP analysis</i>	130
<i>Egress time through “Belgium” and density in the reservoir area</i>	131
<i>Summary of the results</i>	133
<i>Conclusion</i>	138
References	138
Willem van den Berge – the Rotterdamse Elektrische Tram (RET)	142
<i>About Willem</i>	142
<i>Introduction</i>	142
<i>Introduction Zuidplein</i>	142
<i>Introduction: The Flying Dutch</i>	143
<i>Research objective</i>	143
RAMP	144
Routes	144
<i>Overview of available routes to and from Zuidplein from Rotterdam Ahoj</i>	144
Area	145
Zone 1	146
Zone 2	147
Zone 3	148
Movement	148
Ingress	149
Egress	150
Profile	152
DIM-ICE	152
Risk mapping	155
Ingress	155
Egress	155
Decision support analysis	155
Conclusion	156
Roderick van Gelder – Cold Chisel at Parramatta (Australia)	158
Case Study – Cold Chisel	159
The band	159
Demographics	159
Modes of transport	159
Arrivals on site	160
The concert	162
Access to the concert site	162
Circulation	163
Egress	164
Emergencies	166
Crowd movement	168
Traffic Management	169
Food and Beverage	170
Risk maps	171
References	172

Eric Kant - Wantijpop	173
<i>About Eric</i>	173
<i>Introduction</i>	173
<i>Key aspects of the event</i>	173
<i>Plan</i>	174
<i>Ingress</i>	175
<i>Circulation</i>	175
<i>Egress</i>	176
<i>Emergency route</i>	176
<i>Key aspects of the site</i>	177
<i>Fencing</i>	177
<i>Entrance</i>	177
<i>Main stage area</i>	177
<i>Final exits</i>	178
<i>Emergency exits</i>	178
<i>DIM-ICE normal</i>	178
<i>DIM-ICE emergency</i>	179
<i>Conclusions</i>	180
<i>Primary risks:</i>	184
<i>Recommendations – Overall</i>	187
<i>Decision support analysis</i>	187
<i>Ingress</i>	189
<i>Circulation</i>	189
<i>Egress</i>	189
References	190
USM - NCS ⁴	191
<i>The University of Southern Mississippi (USM)</i>	191
<i>Training and education</i>	191
<i>Crowd management training and resources in the United States</i>	192
<i>Research</i>	192
<i>Outreach</i>	193
Final word	194

ACKNOWLEDGEMENTS

These are the essays and case studies, originally intended for the printed copy of the book “Applied Crowd Science”. The reason we moved these to the online version was that the reduction of colour graphics to grey scale did not convert well (green was darker grey than orange). Colour graphics highlights the entire aim of the course, to colourise risk for greater impact during multi-agency communications, the grey scale in these case studies simply did not work well enough to display the work completed by the various contributors. The online version is in full colour.

In this online copy, we used the numbering sequence from the original submission. This collection of essays and case studies shows the international use of the modelling tools developed by Prof. Still over the last three decades.

Thank you to all the authors who have contributed papers (we let them introduce themselves in their essays and case studies) in alphabetical order. Aldo Raineri (Australia), Andrew Seeds (UK), Bert Bruyninckx (Belgium), Breda University of Applied Science (Holland), Diarmuid Smyth (Ireland), Eric Kant (Holland), Graeme Clarke (Australia), Ise Murphy (Ireland), Ken Scott (UK), Kevin Kennedy (Canada), Kristin Finn (UK), Manon Gijbels (Holland), Marc Tubee (Holland), Mark Breen (Ireland), NCS⁴ (USA), Roderick van Gelder (Australia), Ryoki Murayama (Japan), Shane Harris (Australia), Sheila Russell (UK), Steve Riches (UK), Syan Schaap (Holland), Tristan Taylor (Australia), Willem van den Berge (Holland). It was a pleasure collaborating with you all, and a huge thank you for your contributions and patience.

A huge thank you to Frazer Merritt of Taylor Francis for all his patience and assistance during the process of producing this book.

ESSAYS ON CROWD SCIENCE

I cannot teach anybody anything, I can only make them think.

Socrates

In this chapter, we highlight delegates' essay work from the short courses taught around the world. When we teach, we challenge every student to assess the crowd science models. If they agree, say so. If they can find fault, then provide an alternative, or augment the models accordingly, but support your option with evidence. Your opinion that "this should be added" is not science, explain why, demonstrate why your version works as an alternative and provide evidence that supports your model. When presented with a new model, such as Mark Breen's LaD classification, which enhances crowd sciences, we can adopt it. One example of this was the addition of "Invacuation" to the strategic alternatives for crowd evacuation alternatives.

We have seen other models, such as the USA "DIME-ICE", which fails to grasp that the elements in the Design, the Information and the Crowd Management *should* shape the crowds' expectations. Adding expectations as a column is counterproductive for two reasons. The first is that the model was based on the history of causality of accidents which we use to view the specific area/section of the site through the lens of past disasters.

We do not see the evidence that "expectations" were a *cause* of an incident; instead of failing to manage, to shape the crowds' expectations was a distal cause. By adding expectations as a causal element, you shift the focus of causality towards the masses.

Expectations are within the context of the decision support models, where you outline your strategy and tactics for crowd management, where you assess how to shape the crowds' expectations. The second issue with adding expectations as a fourth column is that the model no longer fits into the catastrophe theory¹ model that we teach at Level 7 (Masters, MSc in Crowd Safety and Risk Analysis).

Catastrophe theory

Catastrophe theory is a branch of geometry where we depict the variables and resultant behaviours as curves or surfaces. The formal development of the theory is credited chiefly to the French topologist René Thom.

A simple example of the behaviour studied by catastrophe theory is the change in shape of an arched bridge as the load on it is gradually increased. The bridge deforms in a relatively uniform manner until the load reaches a critical value, at which point the shape of the bridge changes suddenly—it collapses.

¹ <https://www.britannica.com/science/catastrophe-theory-mathematics>

The catastrophe surface has three dimensions, and so does the DIM-ICE model. By adding columns – as the USA DIME-ICE, the model no longer fits in the catastrophe theory framework. The same problem applies to a model called “DIM – ALICED – Design, Information, Management – Arrival, Last Mile, Ingress, Egress, Departure”. This model may be useful for events where there is a last mile, but it combines the crowd dynamics and crowd risk in one matrix. These are different concepts and, as such, can only confuse the concepts of localised site risks and crowd dynamics across a wider area. The problem with these, and other derivations, is that they deviate from the primary objective of the DIM-ICE model, which was to collect, collate and communicate a risk assessment of a *specific section* of a site.

The aim of using different tools is to focus the user’s attention that these are different perspectives on risk, and distinct types of analysis. Mix them all together and try and produce one model that does everything, and you are back to the same template currently in use.

We do not advocate trying to fit a too large a area, or a whole event into a DIM-ICE model. As we highlighted in a previous chapter of this book, the DIM-ICE application is multi-scalar, you apply DIM-ICE to sections of a site, then see the larger picture (see the Canada Day example in Chapter 2). Our aim was to produce a more versatile method of differentiating distinctive types of crowd risks for the built and complex environment, hence a toolkit for crowd risk analysis.

Student papers

As we mentioned in earlier chapters, the structure of this book follows the online VLE courses Level 3 – Fundamentals of Crowd Science course. We use the Introduction to Crowd Science course (Level 5) at the core theoretical element for the Minor at Breda University of Applied Science (BUAS). This started in 2019 and we have seen over 100 students pass through the course at BUAS. The first essay in this section is from the winner of the graduate year 2021 essay competition.

Breda University of Applied Science

History of BUAS and event safety and logistics

Breda University of Applied Sciences (abbreviation: BUas) is a medium-sized education institute for higher education established in Breda. Over 7,500 Dutch and foreign students’ study at this institute. Up to and including August 2018, this university of applied sciences was known as NHTV internationaal hoger onderwijs Breda.

Breda University of Applied Sciences was founded in 1966, the year in which the Nederlands Wetenschappelijk Instituut voor Toerisme (NWIT) was established in Breda. This institute primarily focused on tourism, recreation, languages and economics. In 1987, NWIT merged with

Verkeersacademie Tilburg (VAT), established in 1972, and was then called Nationale Hogeschool voor Toerisme en Verkeer (NHTV). In subsequent years, the institute and course offerings were expanding. Internationalisation started to play a more important role, and this was the reason for giving it a new name in 2001: NHTV internationale hogeschool Breda. From that moment onwards, “NHTV” was no longer an abbreviation, but a name in its own right. The name of the institute was again changed after the launch of these study programmes as it was not exclusively a university of applied sciences anymore, and meanwhile enjoyed an international reputation. In 2008, NHTV was therefore named NHTV internationaal hoger onderwijs Breda. In 2018, its name was changed into Breda University of Applied Sciences.

BUas offers, in total, 11 professional bachelor’s programmes in the field of Tourism, Games, Leisure & Events, Hotel, Media, Logistics, Built Environment, and Facility. In some domains, BUas also offers academic bachelor’s programmes. Lastly, the institute offers some professional master’s programmes and workplace learning pathways.

BUas is an international education institute. Some 15% of its students come from abroad. Every degree programme is strongly internationally oriented, and students can participate in international work placements and exchange programmes. The majority of degree programmes are English taught.

Since 2000, attention has been paid to event logistics and crowd safety within the Logistics Management programme with a strong focus on process management and capacity calculations at events. A former BUas lecturer, Maarten van Rijn, is the author of the book *Event Logistics, the Realization of event Concepts in Safe and Service Orientated environments* and was responsible for the launch of the specialisation Event Logistics. Industry partners (among others, Mojo Concerts, Lock7000, De Boer Tenten, Maison van de Boer) requested him to make a substantive contribution to the development of knowledge. “We conducted research and gained experience on site at large festivals”. On this basis, I started to write the book together with Dick van Damme (Amsterdam University of Applied Sciences).

ID&T² gave us ample room to visit festivals such as Mysteryland and Sensation, where research was carried out into processes at festivals. In cooperation with The Security Company, research was conducted into crowd management (among others, AC/DC at the Amsterdam ArenA and Coldplay at Goffertpark). “On the basis of this research and analyses, we designed the basic framework of our book”. Maarten van Rijn saw that in the past 20 years the Event Management courses had devoted a great deal of attention to developing concepts. Van Rijn: “Hardly any or no attention was paid to logistic aspects impacting service and safety. In the last few years, attention for these aspects has strongly increased in the industry as well, and degree programmes have paid more attention to them. Event Management programmes should continuously pay attention to the way in

² <https://www.id-t.com>

which concepts could be implemented, so that events are safe and service oriented. This requires a more quantitative way of thinking”!

In the past, the Leisure and Events degree programme at BUAs mainly focused on Imagineering and creating and putting event concepts in the market. In the last few years, more attention has been devoted to creating concepts aiming at service and safety. The Leisure & Events and Logistics Management degree programmes at BUAs have jointly started a collaboration within the minor Crowd Safety in Hubs & Events.

Development of the minor

Thanks to contributions made by clients such as Marathon Eindhoven, Dutch National Railways, A Day in the Park Festival, the Municipality of Eindhoven, Annual Fair in Alphen a/d Rijn and the World Harbour Days in Rotterdam, the minor Crowd Safety in Hubs & Events launched its first successful edition in September 2009. Events drawing large visitor numbers could cause friction or create bottlenecks. Wonderful challenges students work on during this minor. Students think up practical solutions for, among other things, crowded entrances to a festival site, exit flows at the end of an event or accelerating the flow of visitors at food and drink outlets. On the basis of tried and tested risk analysis models of Prof Dr G. Keith Still (2014) students make venue analyses. They map out, among other things, visitors arriving at and leaving the venue, and circulation during an event. Students visually work out theoretical, yet practically applicable models such as the DIM-ICE Model, the RAMP analysis and congestion mapping. Lastly, collected data provide the input for practical solutions, tested and analysed in 3D simulations.

The DIM-ICE Model of Prof. Dr. G. Keith Still (2009, 2014) considers “Design, Information and Management (DIM)” the three main elements to influence visitors. Design stands for design of the venue; information stands for information and communication aimed at visitors; management stands for organising and directing the organisers. The ICE phases refer to the “Ingress, Circulation and Egress” of an event or activity. Ingress is the inflow process of an activity. Circulation is the phase in which visitors are in and move about an “event” (walking around at a festival, walking from attraction to attraction in an amusement park). Egress means outflow process; the moment visitors leave the activity. Both risks and measures differ in each phase of the activity, the circulation phase. Phases are worked out by means of colour codes on the basis of the colours green (no risk), orange (limited risk) and red (high risk), so this clearly shows readers where the highest risks can be seen.

The combination of DIM and ICE components results in a systematic checklist for risk assessment, and enables measuring and developing crowds (Still, 2014) and physical distancing control. The model is used by students to carry out systematic research for clients for the purpose of mapping out and analysing present risks. The event is addressed from the perspective of a process management idea by making use of what is termed the “Funlane” (from bed to beer and from beer to bed) principle (Van Rijn 2011). Students take a chain approach, in which each activity (inflow, lockers and bar) is a separate process. On the basis

of analysing the funlane (Van Rijn, 2011) and fathoming the customer journey, a good image is given of the various processes. In combination with the various models of Prof. Dr. G.K. Still, this provides a realistic analysis of reality.

Crowd safety and COVID-19

Up until recently, crowd safety mainly focused on places where a crowd comes together at events and in public places. The outbreak of the COVID-19 virus sheds a different light on the matter and the new reality. People should keep their distance: in schools, zoos, theatres, shops, restaurants and city centres. Crowd safety is now part of our society and plays an even bigger role in the leisure industry. Within the minor, therefore, a shift has taken place in terms of clients: the initial focus was mainly on events; COVID-19 was the reason for drawing new clients such as attraction park Efteling, the centre of nightlife Stratumseind, the Vondelpark in Amsterdam and the railway station area Bijlmer Arena.

Organisations and events have to meet government guidelines. This means that people should observe risk-reducing measures, such as social distancing. The knowledge and theory of crowd safety can be applied to organising events with these extra dimensions very well. Crowd safety-related questions concerning process capacities and visitor dynamics are more relevant than ever before. 3D simulation is a useful tool to enable us to answer these questions. If the simulation is provided with the right information, a realistic picture will arise of possible problems in the 1.5-m society. Furthermore, it offers the possibility of testing out and assessing different scenarios.

Start-up Ucrowds, which was established at Utrecht University, is collaborated with within the Crowd Science Hub and in the minor. Ucrowds specialises in crowd simulation software. In cooperation with their partners, they carry out applied research and generate knowledge about safety and visitor experience. Within this partnership, industry partners are cooperated with intensively to seek solutions leading to a safer society within the triangle education, industry and students. One of the first projects that is being carried out within the Crowd Science Hub is Fieldlab Events.

Breda University of Applied Sciences and Logistics Community Brabant engaged in Fieldlab Events. Fieldlab Evenementen is a joint initiative of the event sector, associated in the EventPlatform, the Alliantie van Evenementenbouwers and the government. Its main aim is to bring the event sector back to the old normal. On 15 February 2021, the first test event took place in Jaarbeurs Utrecht. Apart from this business congress, several test events were organised in the period February to May 2021.

Fieldlab Evenementen carried out eight practical tests in the first phase of the research between 15 February and 20 March. These pilots revolved around answering the main question: How do we limit the residual risk arising as a result of events? In the second phase, a series of scaling-up tests took place with a higher visitor density. The new practice-based research had to meet several criteria, such as scaling up, broadening and deepening. Moreover, walk-through locations were added to the research programme. Research is aimed

at testing the conditions on which 1.5-m social distancing can safely be discontinued in various sectors. Central to this research is the question whether the measures which were introduced in previous pilots and turned out good also have a positive effect if there is a higher visitor density or visitor number.

Lecturers and students of the minor Crowd Safety of Breda University (BUas) and staff of Logistics Community Brabant (LCB) are part of the research team at test events. Working on relevant and practical assignments in which, apart from gaining experience, students can also build up their network is crucial within the minor and is also one of the guiding principles of LCB.

LCB is a collaboration between Eindhoven University of Technology, Tilburg University, the Netherlands Defence Academy and Breda University of Applied Sciences. Research is conducted into innovations and renewal within the theme Event logistics together with students of the several partner institutes.

Design and focus of research

Fieldlab Evenementen has determined various building blocks that contribute to prevention of and reduction in the transmission risk of the COVID-19 virus. These building blocks are based on the customer journey of visitors of events. Think of building blocks such as behaviour, track & trace, air quality, visitor dynamics, (rapid) tests, etc. Within the organisation of events, this process should take place in a controlled environment. By paying attention to process management and capacity calculations, a safe environment is created within which desired visitor capacity during events will be possible again. Apart from LCB and BUas, academics and knowledge institutes such as Delft University of Technology and Eindhoven University of Technology are engaged in the research as well as various industry partners and suppliers.

To have events organised again, it is important to have measures validated scientifically in the short term. These may lead to sound substantiation for new regulations. To be able to do so, it is important to have them take place in a real event environment; in concrete pilots during live events; in a controlled, safe and reliable manner. The guiding principle here is testing, studying and analysing the several processes and behaviour at events. The focus of LCB researchers and students doing the minor was mainly on the building block Group Dynamics. By mapping out contact moments, the researchers could answer questions about visitor behaviour. What are the contact moments and what is the contact duration? What are the dynamics of a contact? When we have answers to the questions asked about the several building blocks, we can arrive at a series of risk-controlling measures and a risk model leading to a responsible event environment. The result is a possible testing tool for the government, and regional and local licensing authorities.

Collecting data

For collecting reliable data at Fieldlab Events, students of the BUas minor Crowd Safety in Hubs and Events are made use of. The relevant students mapped out visitor flows and processes at events during the minor under the

supervision of LCB staff. During events, LCB is responsible for collecting data for the benefit of academic research. Within this research, the number of contact moments, contact duration and processes during inflow, circulation and outflow of events is looked at, among other things. Measurements are carried out by means of tags, in combination with video analysis and observations. When research is carried out, the distance is measured very carefully between people in the audience in combination with contact duration.

Students started with a basis in which the several risks have been mapped out on the basis of the DIM-ICE model, the RAMP analysis and Congestion mapping (Still, 2014). On the basis of these risk analyses, students mapped out and analysed the several processes, for example, entrance checks and handing out and collecting tags at the entrance of event venues. Subsequently, students' efforts were made use of for executing the operation and for collecting data.

Various types of events have been chosen with various target groups because you can see the differences and can take measures on the basis of these differences. Per event, several bubbles are tested each having its own dynamics and target group with various instructions. Think, for example, of bubbles at football matches during which 1.5-m social distancing should be observed, choose your own seat in a section, wear/not wear a face mask, free catering services or sing/not sing in a stadium.

Research findings

When data were collected at the several events, public opinion fluctuated noticeably in society. On the one hand, the measures aiming at the spread of COVID-19 were criticised, and on the other hand, the number of patients in intensive care units was rising.

Whereas there were positive reactions to Fieldlab events in the first phase of the research, in the second phase the necessity of this research in relation to a possible third wave in April 2021 was criticised more. For the second phase of the research, it was necessary to test bigger groups because in a context of higher visitor numbers, different types of behaviour are shown. This testing was done at events such as MUD Masters, Eurovision Song Contest, EventSummit and Ready for Takeoff in Enschede, a running event for both recreational runners and racers. For the media, the academic world and society at large it was important at the time to explain well that Fieldlab Evenementen does not conduct any medical research.

One of the main lessons is that the number of contacts – during football matches and theatre performances at any rate – is lower than most people will suspect. Especially entering and leaving event venues and breaks are risky moments. It is also of importance whether people order drinks at the bar during breaks or eat lunch served when seated. Eventually, it will have been mapped out on the basis of the risk taxation model mentioned above how much risk a person runs per hour: to get Covid, end up in hospital or even die. The main condition for reopening events is that organisers ask visitors

to take a rapid test although this need not be done for what are termed Type I events at the risk level “caution”. They also need to take care that there is good ventilation and half the capacity can be used when prevalence is high. When the risk level “concern” has been reached, however, 100% of visitor capacity can be used on certain conditions. Face masks are obligatory, during breaks at any rate, and at other times when visitors are walking around.

Fieldlab Evenementen concludes from the practical tests conducted and subsequent scaling-up tests that higher visitor numbers will be possible at events, including when there is a high level of risk involved. Furthermore, Fieldlab pleads for fully using the available capacity on certain conditions at risk level “concern”, which is step 4 in the opening plan. This holds for all types of events as they have been identified by Fieldlab Evenementen. This is the main conclusion drawn from research that have been conducted and led by head of research Andreas Voss of Radboudumc in the last few months. These conclusions have been translated into a concrete measure matrix. The Alliantie van Evenementenbouwers and EventPlatform call for the government to judge the conclusions and take them into account when formulating their policy.

Fieldlab Evenementen has formulated four types of events:

- Type I – Inside, Passive (theatre performance and congress)
- Type II – Inside, Active (concert and dance event)
- Type III – Outside, Active (football match)
- Type IV – Outside, Active Festival (dance festival or music festival)

REFERENCES

- Still, G. K. (2014a). *Introduction to Crowd Science* (1st edition). Boca Raton: CRC Press.
- van Rijn, M. & Damme, D. (2015). *Event Logistics, the Realization of Event Concepts in Safe and Service- orientated Environments*. Oisterwijk: RijnDam.

Crowd science essays

As we mentioned in earlier chapters, the structure of this book follows the online VLE courses Level 3 – Fundamentals of Crowd Science course. We use the Introduction to Crowd Science course (Level 5) at the core theoretical element for the Minor at Breda University of Applied Science (BUAS). This started in 2019 and we have seen over 100 students pass through the course at BUAS. The first essay in this section is from the winner of the graduate year 2021 essay competition.

Manon Gijbels – Event safety planning

About Manon

Manon Gijbels is a fourth-year International Tourism Management student at Breda University of applied science in The Netherlands. The tourism industry is fascinating to her, because of her own fondness for travel. During her last year of studies, she participated in a minor Crowd Safety in Hubs and Events because of an interest in understanding the causes of crowd incidents/accidents. Moreover, a willingness to understand the management that goes on behind the screens of an event. Once graduated, she is eager to start her career and excited to broaden her horizon. A future career goal being to work in the field of crowd safety and to contribute to a future in which “the safety of the people is the highest law”.

Crowd science essay

An event safety plan should incorporate crowd science

I remember visiting Pinkpop Festival a week and a half after the Manchester Arena bombings in 2017 (Chan & Smith, 2017), which changed my outlook on visiting such a big event. My mother told us to be aware of anyone wearing a backpack and to look for emergency exits anywhere we were on the festival.

The subject Crowd Science and all its' components like dynamics, behaviour and analysis are a fairly new and unknown topic to many. Most individuals visit a festival and are unacquainted with the “what ifs” that roam the minds of crowd safety specialists. We live in a world where terrorist attacks and mass shootings have taken over the news, before COVID-19 happened at least, which scared people from visiting concerts, going on holiday or even to school (Cigna, 2016). Thankfully, there is an increasing number of specialists to help strive for a future in which “the safety of the people is the highest law” (Cicero, 45BC). Which is why my vision for the future of event safety is a customary event safety plan with strict guidelines that is based on the different risk levels, like in the UK (Health and Safety Executive, sd).

Crowd science can be defined as understanding the causality for crowd incidents/accidents. These incidents mostly transpire at concerts, sporting events and festivals, so places where a large crowd is present at a site. Most disasters occur because of a mismatch between the capacity of the area and the number of people trying to move into the space. These accidents are connected to either crowd behaviour, dynamics or risk analysis (Still G. K., 2019). Crowd simulations are also a tool used in crowd science. Most of which were reasonably foreseeable when they were still on the drawing table. Predictable is preventable.

Crowd simulation is the process of simulating the movement (or dynamics) of a large number of entities or characters (Thalmann, 2016). It allows for experimenting in a way that is not possible in real life, for obvious safety reasons. Moreover, it shows how risks develop into incidents and how these can turn into disasters (Vergunst, 2020).

Nevertheless, this computer-generated version is not the same as the real world. Simulations are very helpful and have added significant value to the world of crowd science, but they can be misleading. The person that is responsible for the simulations might make it look safe and feasible, but an expert needs to be available to interpret the results. This is similar to the reviewing of event plans, if done by a person with little knowledge on the subject it can lead to dangerous situation (BBC, 2017).

The first element of crowd science is crowd behaviour which is defined as a behaviour that is shown by individuals who gather in a crowd (Wijermans, 2011). It is difficult for experts to predict every factor that has an influence on crowd behaviour. Nevertheless, it is crucial that this behaviour is considered as one person's position, under certain key conditions, can have a substantial impact on the outcome of a situation. For example, a small fight that turns into a violent conflict could cause panic and insecurity among visitors.

Next, crowd dynamics can be described as the study of how and where crowds form, and move, above the critical density threshold of more than one person per square meter. The key theory of dynamics is the difference between low and high density. At low density (less than one person per square metre) people can move around freely and choose their routes and directions while reacting to their surroundings. High density (more than six/seven persons per square metre) could result in potential injuries and overcrowding (Still G. K., 2019). This is a crucial element in event planning as a significant number of incidents occur (Spence, 2020), because of the disparity between the area's surface and the amount of people trying to enter that space.

Following, a risk analysis is a process in which a risk is identified, and a value is assigned to that risk (Still G. K., 2019), so recognizing dangerous situations when planning and assessing events. This crowd risk analysis is a concept that takes up a lot of time and effort as it must be done thoroughly to ensure a safe event.

Crowd risks in the event space are related to the static and dynamic risks. A static space is an area where the crowd is mainly stationary, and the opposite is a dynamic space where people are mostly moving (Still G. K., 2019). This is important to know as starting point as it shapes the crowd's behaviour and how they will react to risks.

There are also three modelling techniques used for capturing and communicating event risk, such as a RAMP analysis, DIM-ICE meta-model and matrix analysis technique. The first mentioned instrument, a Route, Area, Movement, Profile analysis is a qualitative process that is performed while assessing and designing an event site both under normal and emergency circumstances. The next tool, a DIM-ICE meta-model (Design, Information, Management – Ingress, Circulation Egress), is used to collect information focused on crowd risks. The template allows the user to assess the behavioural influences of a crowd with an emphasis on the analysis during the different phases. Another technique to evaluate the effectiveness of a strategy is a decision-support analysis which allows the user to map one set of variables (weather) against another (bars) and colour the table to indicate

the potential congestions. This technique helps identify how, for example, a change in the weather impacts the crowd.

Last but not least, a risk map can be created to highlight where congestions or queue forming might occur during a particular phase or at a certain area of the event (Still G. K., 2019).

All these previously mentioned tools also use colour coding. The colour *red* is the high-risk indicator, *orange* portrays medium risks for the crowd and logically *green* means low risk. Colours are there to highlight potential risks and moments when extra attention is required (Still G. K., 2019).

These aforementioned definitions all are quite fixed and generalised. Yet, the situations in which, for example, crowd dynamics are analysed are each influenced by external events such as weather changes, design of buildings and management styles. Moreover, these colours seem a bit vague and can be interpreted by the analyser in his/her own way. My opinion on a risk will differ from somebody that knows nothing or a specialist on crowd safety. This could lead to situations in which a risk is interpreted wrongly resulting in fatal incidents.

Also, as many organisers are not familiar and lack knowledge in the field of crowd safety, how can they be asked to draw up an event safety plan? Letting a person without sufficient understanding create a RAMP-analysis or DIM-ICE model would be seen as something to get done, or try to please the municipality, instead of a tool to ensure safety at their event.

There are sadly enough examples in which crowd injuries could have been prevented. One of these is the monster truck that crashed into the crowd during an 'AutoMotorSportief' event which took place on the 28th of September, 2014, in Haaksbergen, The Netherlands. A so-called monster truck, a self-built stunt truck of 1500 hp with very large wheels, was supposed to drive over parked cars, at high speed, and turn back around but due to a fault in the relay the rear wheels did not steer, and it drove into the public. Three people died and almost 30 were injured in the incident (RTL Nieuws, 2014). Safety was not the first and main priority here which resulted in terrible, preventable sufferings.

Event planning is something that takes up a lot of time and significant amount of money. Around the world, event organisers are planning more and more events while doing their best to minimise expenditure and maximise profit. Most organisers are familiar with the different contracts, building codes and marketing. Moreover, they know how many emergency exits are needed and how wide it needs to be but assessing the site for its unique elements and how these could mitigate risks is where organiser lacks in knowledge. Many of the safety event plans presented are simply a copy of last year's event because "why change if it worked out fine last time?" (Still G. K., 2019).

Event safety plans are a requirement for licenced UK events (Health and Safety Executive) but is different per region in the Netherlands (Ferrari, 2019). The permit holder (usually the organisation of the event) is responsible for the order and safety of the participants and visitors on the event site. As any event, how small it may be, can involve risks. The event permit states which measures an organiser must take to guarantee public order, health and (fire) safety during

the event and how incidents must be dealt with (Vrie, 2020). Also, a good safety plan can help when something should go wrong despite all precautions. The plan clearly describes what was done to prevent these risks and shows that the organiser has taken all precautions to prevent it.

Yet, the costs and time that need to be put into creating an event safety plan are an argument from the point of view of an event organiser. These businesses survive on profit and need to maintain cost controls to do so; safety does not add to the profits at all. Safety managers have different interests than event organisers do maximise safety versus maximise investment. The safety budget is always under pressure as it needs to compete with the goal of maximum returns. For example, simulations are a great way to get an understanding of crowd risks and enable one to experiment with behavioural assumptions. Sadly, the costs of a crowd simulation system are quite high and do not always fit in the safety budget (Still G. K., 2019). Nevertheless, the consequences, for both visitors and the organisation, of a possible incident outweigh the costs of a safety plan by far.

It baffles me that these event safety plans are not a requirement in the Netherlands. As mentioned before, there have been enough incidents already and when are we going to learn? The arrival of national Handreiking Evenementenveiligheid (HEV) strengthened the work process at municipalities in 2012. They created a document that contains a description of the organisation and process surrounding events. It serves as a guideline for municipalities and safety regions. Regrettably, the HEV is not the national standard for work processes resulting in most municipalities carrying out these procedures their own way. The differences between cities, regarding work processes, are bigger than they should be (Schaap, GEMEENTEN MOETEN ÉÉN KADER GEBRUIKEN VOOR VEILIGE EVENEMENTEN, 2015).

To get back to Haaksbergen, the permit for the event was provided on a “routine” basis as it had been hosted seven times before, so it was handled as a normal regular application by officials. These officials did not seek advice from the police or fire brigade, as it is not common at such an event, according to the municipality (NOS, 2014). A risk assessment would have shown where dangers could occur. A RAMP analysis would have highlighted that the Area where the event took place was too small for a monster truck to do its stunt safely. Also, the crowd was standing too close to the stunt and did not have enough space to safely get away in case of danger. Moreover, international guidelines from the Monster Truck Racing Association, an American and European organisation, state that the public is not allowed to be standing where the vehicle is going (Monster Truck Racing Association, 2014).

A thorough risk assessment would have shown the possibility of the event resulting in an incident was “reasonably foreseeable”. The organiser, AutoMotorSportief, was negligent in taking the necessary precautions in drawing up a sufficient event safety plan; moreover, failing to take the responsibility of guaranteeing a safe environment. The mayor (municipality) should have said no in the interests of public order, safety, public health and the environment. According to the committee, he made a wrong assessment of

interests and did not act according to the rules. Furthermore, the requirements that were set for the event were inadequate and impossible to enforce (NOS, 2015).

Event safety plans are checked and approved by the organiser, host city and emergency services. The assessment of these plans is dependent on the subjective opinion of a police officer, fire marshal and municipality employee (Schaap, GEMEENTEN MOETEN ÉÉN KADER GEBRUIKEN VOOR VEILIGE EVENEMENTEN, 2015). These are qualified people who work these positions and are hopefully specialists in the work field.

The common basis is important in these assessments, if these people would all have the same framework and guidelines then the assessment would become less person-dependent.

My opinion is that the document provided by the HEV should be compulsory for every event organiser to provide to the host city. It would be a set document, no differences per region, at events. This would require organisers to analyse the whole event site and to zoom in on spots where possible dangerous situation could occur.

In the case of Haaksbergen, a permit was provided based on an application that did not even mention the word “monster truck” while this was part of the event all along (RTL Nieuws, 2015). A change in event should have, logically, resulted in a change in the event plan. But even if it was mentioned in the application, knowledge and expertise are necessary to recognise and manage special risks, such as with stunts. The licensing authority must be able to recognise these risks and propose appropriate measures. In many (smaller) municipalities, like Haaksbergen, this knowledge is not always available and there is a lack of a network to exchange this necessary knowledge and experience (Onderzoeksraad voor Veiligheid, 2015).

The proximate cause in Haaksbergen was that the relay of the rear wheels did not steer. There were also multiple distal causes like the crowd being too close to the stunt and the event site was too small for a huge monster truck to safely do the trick. Moreover, it was a design-related incident as the site proved inappropriate for its intended use. Long discussions can be held on whose fault it was, but the fact is that the event, in its current form, should have never taken place in such a small area (RTV Oost, 2014).

Crowd science and crowd safety can be better incorporated into event planning, licensing/permitting/approval and event delivery by having a customary event safety plan with strict guidelines. All event organisers should be obliged to participate in a course or workshop like the ones given by Keith Still (2019). Once all those people are aware of how easy it can be for a disaster to occur and how equally simple the solutions can be, it could contribute to a future of which crowd disasters are not part of.

My vision for the future of event safety is a set document with strict guidelines that is based on the different risk levels, like in the UK. Every organiser that wants to host an event should be obliged to deliver a safety plan to the different stakeholders within the city, such as the fire brigade, police

and municipality. The document should include a thorough risk assessment with a RAMP analysis, DIM-ICE model and congestion maps, etc. It forces the organiser to reflect upon their event and look at it from a different angle, so instead of only looking at it from more of a visitor's point-of-view also from a safety perspective. These assessments are executed before the event takes place, so instead of trying to patch up mistakes or looking at close calls after, these wrongs are corrected beforehand.

There is still a great deal to be learned about the new topic of crowd science, such as with unique challenges like a pandemic and a six-foot society. Thankfully, we are learning from past experience, in which a mandatory safety plan can help, while trying to prevent those incidents from happening again, as "those who cannot learn from history are doomed to repeat it" (Santayana, 1906). We are striving for a future in which safety is the most important value, at events but also in the public space (06.01.2021, Gorinchem).

REFERENCES

- Ahoy Rotterdam. (n.d.). Veelgestelde vragen. Available at: Ahoy: <https://www.ahoy.nl/informatie/veelgestelde-vragen> [Accessed 8 Jan. 2021]
- Association, M. T. (2014, January 1). Veiligheidseisen International Monster Truck Racing Association. Available at: Instituut Fysieke Veiligheid: <https://www.ifv.nl/kennisplein/evenementenveiligheid/publicaties/veiligheidseisen-international-monster-truck-racing-association>
- Bardy, M. (2020, May 25). COVID-19: Space Requirements & Crowd Density. Available at: Siflux: https://www.siflux.com/wp-content/uploads/2020/05/Covid19_space_density.pdf
- BBC. (2017, September 19). Computer simulation. Available at: BBC: <https://www.bbc.co.uk/bitesize/guides/zvxp34j/revision/3>
- Centraal Bureau voor de Statistiek. (2012). Babyboomers. The Hague: Centraal Bureau voor de Statistiek.
- Chan, S., & Smith, R. (2017, May 22). Ariana Grande Manchester Concert Ends in Explosion, Panic and Death. The New York Times. Available at: <https://www.nytimes.com/2017/05/22/world/europe/ariana-grande-manchester-police.html>
- Chapter 15: Mode Split. (2014). Available at: <https://www.icpsr.umich.edu/CrimeStat/files/CrimeStatChapter.15.pdf>
- Cicero, M. T. (45BC). De Legibus. Roman Republic.
- Cigna. (2016, March). Coping with Fear of Violent Attacks and Terrorism. Available at: Cigna: <https://www.cigna.com/individuals-families/health-wellness/coping-with-fear-of-terrorism>
- Computer simulation. (2017, September 19). Available at: BBC, <https://www.bbc.co.uk/bitesize/guides/zvxp34j/revision/3>
- Coping with Fear of Violent Attacks and Terrorism. (2016, March). Available at: Cigna, <https://www.cigna.com/individuals-families/health-wellness/coping-with-fear-of-terrorism>
- Dijk, R.-J. v. (2020, October 27). Mobility. Breda, The Netherlands.

- Dordrecht Marketing. (2021). Weekmarkt Statenplein & Sarisgang. Available at: Centrum Dordrecht, <https://centrumdordrecht.nl/locatie/weekmarkt-statenplein-sarisgang/>
- Dordrecht Marketing & Partners. (2020). Stadsplattegrond Dordrecht. Available at: Centrum Dordrecht, <https://centrumdordrecht.nl/plan-je-bezoek/stadsplattegrond-dordrecht/>
- Drama bij evenement Haaksbergen. (2014, September 28). Available at: RTL Nieuws, <https://www.rtlnieuws.nl/nederland/artikel/1624806/drama-bij-evenement-haaksbergen>
- Drama monstertruck Haaksbergen: vergunning gemeente onterecht. (2015, October 28). Available at: RTL Nieuws, <https://www.rtlnieuws.nl/node/893851>
- Esselink, R., Lenderink, T., & Nijenhuis, H. (2018, May). De Marktbezoeker. Available at: Centrale Vereniging voor de Ambulante Handel, <https://www.cvah.nl/de-marktbezoeker/>
- Ferrari, C. (2019, March 22). Vergunning aanvragen voor je evenement – een handig stappenplan. Available at: eventbrite, <https://www.eventbrite.nl/blog/vergunning-aanvragen-evenement-ds00/>
- Forsyth, D. R. (2014). Group Dynamics. Belmont: Wadsworth Cengage Learning.
- Gebrek aan alertheid bij vergunning monster truck in Haaksbergen. (n.d.). Available at: Onderzoeksraad voor veiligheid, <https://www.onderzoeksraad.nl/nl/page/6913/gebrek-aan-alertheid-bij-vergunning-monster-truck-in-haaksbergen>
- Groeneweg, J. (2020, May 4). Dordtse weekmarkt grotendeels goed verlopen: ‘Maar sommigen zagen het toch als een uitje’. Available at: AD, <https://www.ad.nl/dordrecht/dordtse-weekmarkt-grotendeels-goed-verlopen-maar-sommigen-zagen-het-toch-als-een-uitje~a0fe9eac0/>
- Hart van Zuid. (2020). Compleet vernieuwde busterminal Zuidplein. Available at: <https://www.ahoy.nl/informatie/veelgestelde-vragen> [Accessed 8 Jan. 2021]
- Health and Safety Executive (n.d.). Retrieved from: <https://www.hse.gov.uk>
- Lieve, M. d. (2018, June 4). Bijna vier jaar na monstertruckdrama doet chauffeur zijn verhaal: “Kon ik het maar terugdraaien”. Available at: NH Nieuws, <https://www.nhnieuws.nl/nieuws/225741/bijna-vier-jaar-na-monstertruckdrama-doet-chauffeur-zijn-verhaal-kon-ik-het-maar-terugdraaien>
- Monster Truck Racing Association. (2014, January 1). Veiligheidseisen International Monster Truck Racing Association. Available at: Instituut Fysieke Veiligheid, <https://www.ifv.nl/kennisplein/eventementenveiligheid/publicaties/veiligheidseisen-international-monster-truck-racing-association>
- NOS. (2014, September 30). Vergunning Haaksbergen "routine". Available at: NOS, <https://nos.nl/artikel/704609-vergunning-haaksbergen-routine.html>
- NOS. (2015, February 17). ‘Vergunning monstertruck ten onrechte verleend’. Available at: NOS, <https://nos.nl/artikel/2019891-vergunning-monstertruck-ten-onrechte-verleend.html>
- Onderzoekcentrum Drechtsteden. (2020). Bevolking - Dordrecht. Available at: Onderzoekcentrum Drechtsteden, https://ocd.buurtmonitor.nl/jive?cat_open_code=c1
- Onderzoekcentrum Drechtsteden. (2020). Monitor Coronacrisis. Sliedrecht: Onderzoekcentrum Drechtsteden.

- Onderzoeksraad voor Veiligheid. (2015, May 20). Gebrek aan alertheid bij vergunning monster truck in Haaksbergen. Available at: Onderzoeksraad voor Veiligheid, <https://www.onderzoeksraad.nl/nl/page/6913/gebrek-aan-alertheid-bij-vergunning-monster-truck-in-haaksbergen>
- Oozoo. (2020). Wetenswaardigheden, cijfers en statistieken over Dordrecht. Available at: Oozoo, <https://www.oozo.nl/cijfers/dordrecht>
- RET. (2019, February 22). Cijfers metro: Rotterdam Beurs is drukste metrostation van Nederland. Available at: Treinreiziger: <https://www.treinreiziger.nl/cijfers-metro-rotterdam-beurs-is-drukste-metrostation-van-nederland/> [Accessed 8 Jan. 2021]
- RET. (2019). Jaarverslag 2019 RET. Available at: <https://corporate.ret.nl/media/2899/jaarverslag-2019-ret.pdf> [Accessed 8 Jan. 2021]
- RTL Nieuws. (2014, September 28). Drama bij evenement Haaksbergen. Available at: RTL Nieuws, <https://www.rtlnieuws.nl/nederland/artikel/1624806/drama-bij-evenement-haaksbergen>
- RTL Nieuws. (2015, October 28). Drama monstertruck Haaksbergen: vergunning gemeente onterecht. Available at: RTL Nieuws, <https://www.rtlnieuws.nl/node/893851>
- RTV Oost. (2014, September 29). 'Verantwoordelijkheid voor ongeluk Haaksbergen ligt bij gemeente en organisatie' 1200 kbps geselecteerd als afspeelkwaliteit Veel hulpverleners in Haaksbergen (Foto: Erik Schaddelee) Veel hulpverleners in Haaksbergen (Foto: Erik Schaddelee) Syan S. Available at: RTV Oost, <https://www.rtvooost.nl/nieuws/199444/Verantwoordelijkheid-voor-ongeluk-Haaksbergen-ligt-bij-gemeente-en-organisatie>
- Santayana, G. (1906). Reason in Common Sense.
- Schaap, S. (2015, June 10). GEMEENTEN MOETEN ÉÉN KADER GEBRUIKEN VOOR VEILIGE EVENEMENTEN. Available at: Centrum voor criminaliteitspreventie en veiligheid, <https://ccv-secondant.nl/platform/article/gemeenten-moeten-een-kader-gebruiken-voor-veilige-evenementen>
- Schaap, S. (2020, September 10). Crowd Safety and Risk Analysis. Breda, The Netherlands.
- Spence, S. (2020, October 28). Right-wing extremism: The new wave of global terrorism. Available at: World Economic Forum, <https://www.weforum.org/agenda/2020/10/right-wing-extremism-global-terrorism/>
- Statista. (2019, September). Number of festivals in the Netherlands from 2013 to 2018. Available at: Statista, <https://www.statista.com/statistics/673435/number-of-festivals-in-the-netherlands/>
- Still, G. K. (2019). *Introduction to Crowd Science*. Boca Rotan: Taylor & Francis Group.
- Thalmann, D. (2016). Crowd Simulation. In N. Lee, Encyclopedia of Computer Graphics and Games (pp. 1–8). Springer International Publishing.
- van Driel. (2020, April 29). Markten in Zuid-Holland Zuid weer toegestaan, maar wel onder extra toezicht. Available at: AD, <https://www.ad.nl/dordrecht/markten-in-zuid-holland-zuid-weer-toegestaan-maar-wel-onder-extra-toezicht-aa6efc74/>

- van Driel. (2020, April 30). Nieuwe regels tijdens de Dordtse weekmarkt: 'Houd afstand en blijf niet langer dan nodig'. Available at: AD, <https://www.ad.nl/dordrecht/nieuwe-regels-tijdens-de-dordtse-weekmarkt-houd-afstand-en-blijf-niet-langer-dan-nodig~a5b28df5/>
- van Driel, I. (2020, April 29). Markten in Zuid-Holland Zuid weer toegestaan, maar wel onder extra toezicht. Available at: AD, <https://www.ad.nl/dordrecht/markten-in-zuid-holland-zuid-weer-toegestaan-maar-wel-onder-extra-toezicht~aa6efc74/>
- van Driel, I. (2020, April 29). Markten in Zuid-Holland Zuid weer toegestaan, maar wel onder extra toezicht. Available at: AD, <https://www.ad.nl/dordrecht/markten-in-zuid-holland-zuid-weer-toegestaan-maar-wel-onder-extra-toezicht~aa6efc74/>
- van Driel, I. (2020, April 30). Nieuwe regels tijdens de Dordtse weekmarkt: 'Houd afstand en blijf niet langer dan nodig'. Available at: AD, <https://www.ad.nl/dordrecht/nieuwe-regels-tijdens-de-dordtse-weekmarkt-houd-afstand-en-blijf-niet-langer-dan-nodig~a5b28df5/>
- van Driel, I. (2020, April 30). Nieuwe regels tijdens de Dordtse weekmarkt: 'Houd afstand en blijf niet langer dan nodig'. Available at: AD, <https://www.ad.nl/dordrecht/nieuwe-regels-tijdens-de-dordtse-weekmarkt-houd-afstand-en-blijf-niet-langer-dan-nodig~a5b28df5/>
- Vergunning Haaksbergen "routine". (2014, September 30). Available at: NOS, <https://nos.nl/artikel/704609-vergunning-haaksbergen-routine.html>
- 'Vergunning monstertruck ten onrechte verleend'. (2015, February 17). Available at: NOS, <https://nos.nl/artikel/2019891-vergunning-monstertruck-ten-onrechte-verleend.html>
- Vergunst, N. (2020, June 2). Crowd simulation software visualises layout for social distancing. Available at: Utrecht University, <https://www.uu.nl/en/news/crowd-simulation-software-visualises-layout-for-social-distancing>
- Voerknecht, H., & van Bokhorst, M. (2018, March). Benchmark actieve, gezonde, duurzame mobiliteit gemeenten. Available at: CE Delft, https://www.ce.nl/assets/upload/file/Rapporten/2018/4N74/CE_Delft_4N74_Benchmark_actieve_gezonde_duurzame_mobiliteit_gemeenten_DEF.pdf
- Vrie, K. d. (2020, June 21). TIP! - Welke vergunningen heb ik nodig om een evenement te organiseren? Available at: eventplanner, https://www.eventplanner.nl/nieuws/4569_tip-welke-vergunningen-heb-ik-nodig-om-een-evenement-te-organiseren.html
- Westland, E. (2020, March 13). Druk op de markt na maatregelen corona: 'Iedereen wil wat extra's te eten in huis hebben' Met name eieren zijn vandaag niet aan te slepen op de markt in Kanaleneiland. Foto: RTV Utrecht / Evie Westland Met name eieren zijn vandaag niet aan te slepen op de. Available at: RTV Utrecht, <https://www.rtvutrecht.nl/nieuws/2027385/druk-op-de-markt-na-maatregelen-corona-iedereen-wil-wat-extras-te-eten-in-huis-hebben.html>
- Wijermans, F. E. (2011). Understanding crowd behaviour: simulating situated individual. Groningen: University of Groningen, SOM.

Íse Murphy – introduction to crowd science and Risk Analysis

About Íse

Íse is a qualified international event professional, experienced in consulting on and designing high scale, high profile events and festivals. With specialist focus on crowd safety and transport planning, her passion lies in combining academic research with industry experience to improve crowd safety practices. She currently works at Wembley National Stadium as Senior Crowd Safety Manager. Íse holds an MSc in Crowd Safety and Risk Analysis, NEBOSH National Certificate in Fire Safety and Risk Management, NVQ Level 4 Spectator Safety Management and BSc in Event Management. She is a member of United Kingdom Crowd Management Association, International Institute of Risk and Safety Management and the Institute of Place Management.

Introduction

Most people have experienced being part of a crowd, whether at a sporting event, a music event, in the everyday commute at a transport hub, during their purchase of goods and services or in several other activities that are carried out every day. More often than in the past, there are occasions and situations where crowds appear owing to an increase in population, more choice in event and shopping destinations and the plethora of organised and non-organised activities taking place locally, regionally and nationally. Without the appropriate control and influence of crowds through design, information and management, disaster can occur.

Extreme crowding may result in individual loss of control, and both the occurrences of psychological and physiological problems (Fruin, 2002). For example, in recent years, the application of thoughtful planning has developed in transport hubs such as the London Underground and Network Rail stations. However, there is a lack in thorough crowd management planning for many events (Smith, 1995). According to Reicher (2008) the study of crowd processes is all but ignored by the dominant paradigms in social psychology.

Having highlighted the lack of study in this specific area it is clear from the range of case studies available that this is reflected in the organisation of events in a modern society. There is a shortage of trained and qualified crowd managers in the area of event management, as the importance of such training has only surfaced in the last three decades. Many disasters at events, as highlighted by (Fruin, 2002), are avoidable, with the correct application of knowledge and training in how to apply the processes in the field.

The legal fallout from these disasters will normally focus on those that failed to produce the correct documentary evidence, those that failed to log the outcomes and those that failed to link the risk assessment to the event plan. This puts pressure on event organisers and those who are responsible for the crowd and crowd movement.

The purpose of this paper is to discuss crowd science, and even though there are in depth studies conducted in other areas of social psychology, the focus on crowd science, dynamics and practical application in modern society is still in its infancy (Reicher, 2008). The paper begins with a definition of crowd science, discusses the theories that underpin it, the legality that surrounds it, the importance of it in the event management industry. To conclude, the paper will evaluate models and tools that can help predict and manage crowd behaviour and movements.

Crowd science

When accidents happen (the Titanic disaster for example), too often the proximate cause (the iceberg) is blamed rather than the distal cause (the captain and crew assumed that the ship could not sink and thus an inappropriate number of lifeboats were provided). Crowd science identifies and purports to provide solutions to a series of perceived problems removing the distal cause of the accident in the first place and creating good practice which will ensure that the outcomes of the project will provide good practice to take into further deliberations about such activities in the future.

Crowd science is a concept that was born from the work of Still (2000) on Crowd Dynamics. He defines this as.

...the study of how and where crowds form and move above the critical density of more than one person per square metre (Still, 2014)

Smith (1995) stated that the suggested density of occupancy for crowds stated in an early version (1990) of the “Green Guide” meant that the entire population of the world could be contained within a circle of radius of 19km. He goes on to say that “clearly these unnatural and unusual circumstances call for careful thought about the arrangements which allow people to enter and leave facilities” (Smith, 1995).

Crowd science is incredibly important in today’s society owing to the large number of planned (and unplanned) events taking place and in association the weight of the liability placed on an event owner. Documentation and sourced legislation and guidance are usually required in planning documentation to be granted sufficient permissions to hold an event. The support of a formal qualification in crowd science would greatly help an event organiser plan efficiently for crowd movements in and around their event or venue, from transport hub to walk up. However, experiential knowledge and on-site expertise are also important in the delivery of a safe event. Qualification in crowd management planning and event management are also crucial in developing the rounded individual that is ready to deliver an event in the safest possible way. Major accidents in the past that have been documented may have been avoided by using simple crowd management models and tools in the planning phase (Fruin, 2002) (Still, 2014).

Concepts of crowd science

There are a number of theories that underpin Crowd Science, and these are laid on in this paper. Crowd density refers the number of people or objects in a designated space and provides a guideline in reference to how many people can safely stand or move through an area. This is generally set at 2 people per square metre for movement and up to 4 people per square metre for a static crowd viewing a concert. Crowd dynamics illuminates how people move through an area whereas crowd behaviour relates to how people act in different situations including but not mutually exclusive to emergency evacuations. Zitouni et al (2015) states that crowd behaviour analysis is a critical application domain for crowd management and situational awareness. Activities such as crowd monitoring can support the analysis and prediction of crowd behaviour. Crowd science aims to understand the psychology of human behaviour in a crowd in a normal or emergency situation and, from this, supports the event planner to anticipate, prevent, respond and recover in terms of an incident and its preponderance.

Legal framework

Crowd science, movement and capacities are supported by a legal and guidance framework. The most referred to the “Guide to Safety at Sports Grounds, HSE 2008” (The Green Guide), The Event Safety Guide, HSE 2014 (The Purple Guide) and BS 9999. There are several documents that are available to support those planning capacities for events.

The Green Guide states in Section 3.3 that to meet the appropriate safety standards to permit crowds to enter sports grounds, certain legislation must be met to demonstrate responsibility for safety. Examples of this include the fire certificate, the safety certificate and the health and safety at work legislation. Adhering to these regulations is crucial to ensure the safety of visitors. However, these regulations lack the structural flexibility related to the dynamics, psychology, management and control of crowds in normal and emergency circumstances. This is where Crowd science can bridge that gap.

Crowd risk analysis

Risk assessments must be completed by an organiser wishing to obtain a licence for an event. Correctly preparing these dynamic documents can help to anticipate and dissipate problems, protecting lives. The risk assessment is only one part of the risk management process and the full management strategy to anticipate and obviate as much risk as possible should be delivered. However, Still (2014) states concern about the tendency of many event organisers to “cut and paste” parts of risk assessments from other events into new event plans. Such an act does not allow for the full contemplation of the unique situation relating to a particular event. It is imperative that one is clear in the analysis of risk and having dynamic documentation to support it in the application for event permission. It is the fundamental underpinning structure that supports crowd science and validates the event planning process.

Methods and tools for crowd risk analysis include the DIM-ICE Matrix (Design, Information, Management – Ingress, Circulation, Egress). According to Still (2014) there are three primary influences on crowd movement and behaviour: design, information and management. These influences need to be assessed during the phases of ingress, circulation and egress, and as a fundamental emergency evacuation and normal procedure, it should be calculated for each phase in order to fully scope the crowd dynamics of an event. Examples of methods also include the R.A.M.P. Analysis (Routes, Areas, Movement, Profiles). It is a tool that allows a visual overview of the areas of concern in the three stages of the event – ingress, circulation and egress. First, the routes are mapped, depicting where the spectators are (likely to be) coming from to reach the event. The areas they pass through can be checked using simple formulas to ensure there is enough capacity to handle the crowd movement.

“Movement” refers to the arrival and departure profile of the crowds, for example, is the arrival profile restricted by transport (a train of 900 pax every half an hour or a bus with 80 pax ever 5 min)? Will the crowd arrive early to get to the front of the queue of the event? Finally, to gain a better understanding of how the crowds will behave, analysis is conducted on the “profile” of the spectator attending the event. There is of course a multitude of profiling tools, and any number can be used to create such an analysis.

Monitoring crowd movements and conducting crowd simulations on computer are common practices. Still (2014) recommends planning for crowd movements as much as possible using pen and paper as this process provides real-time distance and movement that a computer program cannot. Utilising modelling techniques assists in the exploration of a situation as the brain can often be tricked by memories, pre-conceptions and other elements which destabilise the outcome. Still (2014) states that “your mind tricks you into seeing the sum of your knowledge and experience”. Fruin (2002) presents the “FIST” model (Force, Information, Space and Time) which is used to provide a basic understanding of crowd disasters. These models and guidelines show that many crowd disasters could have been avoided by simple advanced planning and management techniques (Fruin, 2002).

Conclusion

Crowd managers have a responsibility for the safety of large numbers of people, yet there is little formalised training in crowd management principles and techniques (Fruin, 2002). With more training, awareness and the correct tools to plan events, event planners reduce the risk of incidents and can ensure that the crowd are as safe as possible given the fluid nature of events and their propensity to be destabilised by the unknown unknowns. Crowd safety and risk analysis are crucial additions to the event planner’s toolbox and one that will support the approval process related to the granting of permission to stage an event. Fruin (2002) recommends that every venue accommodating more than 500 persons be required by law to have a certified crowd manager on staff.

REFERENCES

- Fruin, J. (1993). The Causes and Prevention of Crowd Disasters. In Smith, R.A. & Dickie, J.F., *Engineering for Crowd Safety*. Amsterdam: Elsevier Science Publishers BV.
- Health and Safety Executive (1999). *The Event Safety Guide: A Guide to Health, Safety and Welfare at Music and Similar Events* (2nd edition). Surrey: HSE Books.
- Reicher, S. (2008). The Psychology of Crowd Dynamics. In Hogg, M.A. & Tindale, R.S., *Blackwell Handbook of Social Psychology: Group Processes*. St. Andrews: Blackwell Publishers Ltd.
- Smith, R.A. (1995). Density, Velocity and Flow Relationships for Closely Packed Crowds. *Safety Science*. **18**. 321–327.
- Sports Grounds Safety Authority (2008). *Guide to Safety at Sports Ground (The Green Guide)* (5th edition). London: TSO.
- Still, G.K. (2000). *Crowd Dynamics*. Warwick: University of Warwick.
- Still, G.K. (2014). *Introduction to Crowd Science*. London: CRC Press.

Aldo Raineri – crowd safety and crowd risk analysis

Australian Institute of Police Management, Charles Sturt University, Manly, Sydney, Australia.

About Aldo

In December 2011, I retired as the Director of Work Health & Safety Policy & Legislation, after having spent over 20 years in various management and safety roles with the Queensland Government. During that time, I was involved in every major strategic and operational government safety initiative, including the national development of harmonised work health and safety laws and their implementation in Queensland.

I have also been a sessional lecturer, tutor, course developer, educational administrator and project supervisor in the TAFE system and at a number of Universities in Australia for the past 30 years or so. In addition, I have undertaken comprehensive risk assessments and gap analyses, compliance, systems and due diligence audits and evaluation, contingency planning and management, safety management systems development, implementation and evaluation and formulated strategic and operational safety plans for a number of clients. In addition to developing and implementing policies, procedures and systems to achieve compliance, many of these assignments have involved initiating and sustaining a cultural shift in order to achieve compliance and sustainable 'best practice' in risk mitigation, injury prevention, rehabilitation and return to work.

Introduction

Crowds are a characteristic of modern life. Unfortunately, if not properly understood or managed, be it at a sporting or religious event, an entertainment venue or a transports hub, their supervision can be infused with potentially serious consequences. Sime (1993) argued that insufficient attention to the way in which people behave in a crowd and the relationship between behaviour and systems design are major factors leading to crowd disasters. Without understanding crowds and crowd behaviour, Berlonghi (1995) argued that we are left with random attempts at crowd control and crowd management which may result in serious losses including life and those of lesser import which are focused on structural, health or pecuniary related loss

This paper outlines the emerging discipline of crowd science and the important contributions that it can make to planning for safer outcomes at mass gathering events and in crowded spaces of any kind. The paper commences with a formative definition of crowd science and situates it within a broader sociological framework, considering the key elements and theories that underpin it. It goes on to outline the need for crowd science approaches in light of

the inadequacy of traditional risk assessment methods and concludes with an outline of a contemporary framework, laying out the methods and tools that can be usefully adopted to analyse and predict elements of crowd behaviour.

What is crowd science?

Crowd science can be defined as the study of the effect of density, dynamics and behaviour (individual and collective) on a crowd. It stems from the initial work of Still (2000) on *crowd dynamics*, which he defines as “the study of the how and where crowds form and move above the critical density of more than one person per square metre” (Still 2013 p.93). This initial work was augmented by concepts of social psychology and behaviour and expanded by Still (2013) into the more comprehensive term of *crowd science*.³

Crowd science is closely aligned to the notion of *proxemics* developed by the sociologist E.T. Hall. Hall has defined proxemics in various ways over the years, but perhaps the following definition is closest to the concept of crowd science envisaged by Still (2000, 2013):

... the study of man's transactions as he perceives and uses intimate, personal, social and public space in various settings while following out of awareness dictates of cultural paradigms.

(Hall, 1974, p. 2)

This definition has three key components. First, proxemics involves the study of interpersonal interactions. Second, these interactions are viewed in a spatial context, which Hall has defined by four “zones” that he has termed intimate, personal, social and public. Third, this behaviour is largely learned or culturally determined rather than entirely dictated by innate biological or physiological processes.

Key elements of, and theories underpinning, crowd science

Crowd density is the number of people and/or objects in a given space (Drintewater and Gudjonsson 1989) and plays a central role in the appraisal of crowding (Baum, Davis, and Aiello 1978). *Crowd dynamics* relates to the movement of crowds and of individuals within that crowd. *Crowd*

³ The expression is not to be confused with the increasingly common practice in which people pool information (especially in the physical sciences) which they have gathered independently, and then have access to all of the information which they and others have supplied. As a group, they can develop new understanding and produce products that they never could have produced by working in isolation. This is also known as an interdisciplinary approach. In astronomy, for example, far too many galaxies and stars exist for any one individual to observe and analyse. So, the field has shifted dramatically from individual astronomers sitting at their telescopes writing up their discoveries, to networks of astronomers who share their information in a common database which all can use. The author considers this practice should be more appropriately referred to as crowdsourcing rather than crowd science.

behaviour stems from different types of individual and group motivation, including flight/fight responses (in emergency situations) and crowd craze (in non-emergency situations)⁴.

Fruin (1993, p. 40) identified that a density of 7 persons or more per square metre is dangerous and can create serious issues for those managing crowds. Shock waves can be propagated through the mass sufficient to lift people off their feet and propel them distances of up to 3 m or more. Intense crowd pressures exacerbated by anxiety can make it difficult to breathe. The heat and thermal insulation of surrounding bodies cause some to be weakened and faint. Compressive asphyxia from crowd crushing may result in access to those who fall is virtually impossible and those who try to assist risk being trampled along with those affected by the crowd collapse.

The legal, regulatory and risk management framework

Recommendations as to safe crowd densities and operational guidelines have been included in the *Guide to Safety at Sports Grounds* (HSE, 1997) (the “Green Guide”), which defined criteria for sporting grounds, the *Event Safety Guide* (HSE, 1999) (the “Purple Guide”), which defines the criteria for pop concerts and similar events, and the *Guide to fire precautions in existing places of entertainment and like premises* (HSE, 1998) (the “Primrose Guide”), which defines the criteria for existing places of entertainment. However, these guides all differ in their calculations and applications.

The information contained in the “purple guide” has been largely replicated in Australia (EMA, 1999; DoH, 2004; DOH, 2005; DHS, 2003; SafeWork Victoria, 2006a, 2006b; LLD, 1999) and the guide has been reproduced for local conditions in the USA (Event Safety Alliance 2014).

Although these documents are not regulatory in nature, they do have effect in two ways. First, they support the co-regulatory nature of modern occupational health and safety legislation in the UK⁵ and Australia⁶ by outlining measures which can be considered “reasonably practicable” to adopt in the context of crowd risk management. In addition, compliance with the guidelines is often a condition of licensing of events by local authorities in the UK and Australia. This is especially true of the Football Licence in the UK. Although this is the only guidance a football club cannot gain its licence to host football matches unless it has complied with the guidance making it for all intents and purposes law.

⁴ A craze is a competitive rush to obtain some highly valued objective. This type of behaviour is heavily influenced by the psychosocial orientation of the crowd, exuberant personal expression and any sub-cultural characteristics of social movements associated with the theme of an event.

⁵ Health and Safety at Work Act 1974.

⁶ Work Health and Safety Act 2011.

Why is there a need for a crowd science approach?

Minimising adverse health and safety impacts is important to the delivery of successful events. Several studies and enquiries (Bokhary, 1993; Funnell, 1988; Taylor, 1989, 1990) highlight insufficient or inadequate planning as a significant contributing factor to inadequacies in crowd safety at mass gatherings. There is considerable endorsement in the literature for a risk management approach to event planning (Department of Health [DoH], 2004; Emergency Management Australia [EMA], 1999; Federal Emergency Management Association [FEMA], 2003; Health and Safety Executive [HSE], 1999).

However, commentators (e.g.: Upton, 2004, 2008; Still, 2013, 2014) point to a number of shortcomings with the traditional risk assessment approach in the context of assessing risks at mass gatherings. Current methods have been inconsistent (Arbon, 2004) and often ineffective (EMA, 1999), and as a consequence, the quality of risk assessments for mass gatherings, both in Australia and internationally, has been heavily criticised (Weir, 2002; Upton, 1999, 2004, 2008; Wertheimer, 1993). Combined with this the uneasy bedfellows of quantitative and qualitative analytical approaches have never been bottomed out and the lack of a dual paradigm is often disconcerting.

Crowd risk analysis

Still (2014) suggests that conventional risk assessment documents, particularly those that relate to crowd safety, are fundamentally flawed for several reasons. First, the method is biased towards overestimating risk. Second, the process is usually carried out as a form-filling exercise, with writers taking a “cut and paste” approach to the development of their risk assessment. Finally, and most importantly, a person reading a risk assessment does not have enough information, knowledge, or intelligence to address relevant crowd safety issues owing to the condensed format of the typical risk assessment report.

As a consequence, Still comments (2014, p. 48) that the standard crowd risk analysis process of multiplying the likelihood of the risk occurring and the consequence of that risk fails the basic principles of Information Theory (Shannon, 1948) in that it is impossible to reconstruct the conditions that give rise to many crowd related risks, especially those which are dynamic in nature.

A framework for crowd risk analysis

Still (2009, 2014) suggests that there are three fundamental categories of systemic failure common to all crowd related incidents – design, information and management, and that there are three main phases of concern when considering the movement of people in high density environments – ingress, circulation and egress. Ingress relates to the period prior to the event, circulation typically relates to movement within the venue and egress relates to leaving of the event after it is completed.

Still (2009) combines these into a matrix framework, which he calls the DIM-ICE model, which is used to compare the situation during normal and emergency conditions for each phase and influence. The framework is set out at Attachment A.

Methods and tools for crowd risk analysis

Within the DIM-ICE framework, Still (2013) suggests that a RAMP analysis provides a useful approach for modelling crowds. Such an analysis examines the routes, areas, movement and profile at a mass gathering. By utilising this evaluation flow path analysis, flow rates and fill times/capacities can be quickly and easily determined, and the techniques serve as a predictor of crowd activity and behaviour. Still (2013) strongly advocates the use of colour-coded maps, plans, site diagrams and photographs as visual aids to assist this type of analysis.

Conclusion

This paper has briefly outlined the nature and component elements of the nascent discipline of crowd science. The need for such a holistic approach is evident from the shortcomings of using traditional, non-interdisciplinary approaches in the assessment of crowd safety risks.

REFERENCES

- Arbon, P. (2004). The Development of Conceptual Models for Mass-gathering Health. *Journal of Prehospital and Disaster Medicine*. 19(3). 208–212.
- Baum, A., Davis, G., & Aiello, J. (1978). Crowding and Neighbourhood Mediation of Urban Density. *Journal of Population*. 1(3). 266–279.
- Berlonghi, A. E. (1995). Understanding and Planning for Different Spectator Crowds. *Safety Science*. 18. 239–247.
- Bokhary, Mr Justice (1993). The Lan Kwau Fong Disaster on January 1, 1993, Final Report. February 23, 1993, Hong Kong.
- Department of Health [DoH]. (2004). Guidelines for Concerts, Events and Organised Gatherings. Western Australia: DoH Publication.
- Department of Health [DoH]. (2005). Operational Guidelines for Rave Parties, Concerts and Large Public Events. Western Australia: DoH Publication.
- Department of Human Services [DHS]. (2003). Guidelines for the Management of Public Health at Public Events. South Australia: DHS.
- Drintewater, J.A. & Gudjonsson, G.H. (1989). The Nature of Violence in Psychiatric Hospitals, in Howell, K. & Hollin, S. C.R., *Clinical Approaches to Violence*. Chichester: Wiley.
- Emergency Management Australia [EMA]. (1999). Safe and Health Mass Gatherings, Canberra: AGPS.
- Federal Emergency Management Agency [FEMA]. (2003). *Special Events Contingency Planning*. America: FEMA.
- Fennell, D. (1988). *Investigation into the King's Cross Underground Fire*. London: HMSO.

- Fruin, J. (1993). The Causes and Prevention of Crowd Disasters. In Smith, R.A. & Dickie, J.F., *Engineering for Crowd Safety*, Amsterdam: Elsevier Science Publishers BV.
- Hall, E.T. (1974). *Handbook for Proxemic Research*. Washington: Society for the Anthropology of Visual Communication. Taylor and Francis.
- Health and Safety Executive [HSE] (1997). Fairgrounds and Amusement Parks: Guidance on Safe Practice. HSE Publication HS(G) 175.
- Health and Safety Executive [HSE] (1998). Guide to fire precautions in existing places of entertainment and like premises. HMSO London.
- Health and Safety Executive [HSE] (1999). The Event Safety Guide: A Guide to Health, Safety and Welfare at Music and Similar Events. 2nd ed. Surrey: HSE Books.
- Liquor Licensing Division, Queensland [LLD] (1999). *A Planning Guide for Event Management – Alcohol Safety and Event Management* (1st edition). Brisbane: Department of Tourism, Sport and Racing.
- SafeWork Victoria. (2006a). Advice for Managing Major Events Safely, Victorian Workcover Authority.
- SafeWork Victoria. (2006b). Crowd Control for Venues and Events: A Practical Occupational Health and Safety Guide, Victorian Workcover Authority.
- Shannon, C.E. (1948). A Mathematical Theory of Communication, *The Bell System Technical Journal*. 27. 379–423, 623–656.
- Sime, J.D. (1993). Crowd Psychology and Engineering: Designing for People or Ball Bearings? In Smith, R. S. & Dickie, J. F., *Engineering for Crowd Safety*. Elsevier Science Publishers: BV.
- Still, K. (2000). Crowd Dynamics. PhD Thesis presented to the University of Warwick, 2000.
- Still, K. (2009). Safety in Numbers, ISquared, Summer, pp. 23–26.
- Still, K. (2013). Introduction to Crowd Science. Boca Raton: CRC Press.
- Still, K. (2014). Visualising Risk Assessment for Crowd Safety. *Journal of the International Centre for Sports Security*. 2(1). Available at: http://icss-journal.newsdeskmedia.com/images/Upload/Vol_2_n0_1/ICSS_Vol2.1.pdf
- Taylor, Lord Justice (1989). The Hillsborough Stadium Disaster Inquiry Interim Report. London: HMSO.
- Taylor, Lord Justice (1990). The Hillsborough Stadium Disaster Inquiry Final Report. London: HMSO.
- Upton, M. (1999). Britain Updates its Concert Guide. Crowdsafe Newsletter, Crowd Management Strategies, November/December.
- Upton, M. (2004). Risk Analysis for Major Concert Events, the Benefits of Hindsight. Cabinet Office Seminar on Safety at Mass Crowd Events (January 2004), Chicago: Crowdsafe.com Library.
- Upton, M. (2008). Safe Event Management. Paper delivered to the Theatre Managers Association Conference, Birmingham, 10 June.
- Weir, E. (2000). Raves: A Review of the Culture, the Drugs and the Prevention of Harm. *Canadian Medical Association Journal*, 162(13). 1843–1848.
- Wertheimer, P. (1993) The American Experience: Rock Concert Safety. Chicago: Crowdsafe.com Library.

Attachment A

The DIM-ICE Model (Still, 2009)

Kristin Finn – an analysis of crowds for event safety

About Kristin

Kristin Finn is a Lecturer in Event Management for the Department of Tourism and Hospitality at Plymouth University, and her main teaching roles are in crowd management, research and consultancy, and operational planning for events. Specifically, her research interests lie in matters relating to crowd behaviour, managing safety and the relationship between crowds and audience experience at events.

Prior to joining Higher Education, she worked in consultancy for almost ten years, most notably developing project evaluations, monitoring frameworks and organisational strategies for local government as well as visitor and audience behaviour studies for tourism, cultural and events organisations in the public and private sectors. This range of experience informs her teaching contribution and areas of professional interest.

Introduction

In 1995 Berlonghi observed that a crowd in a contemporary setting is a composite of multiple personalities. Thus, it can be argued that crowd identities must be studied in the plural sense (Borch, 2013), as heightened emotions can denote that one crowd can evoke a range of different behavioural patterns at different points during an event episode due to the unique characteristics of the individuals involved and the event-specific catalysts. This paper will explore the characteristics and catalysts commonly considered to have an impact on crowd behaviour in the context of events.

Knowledge of crowd typologies is important for the understanding of audience behaviour at events. Rutherford-Silvers (2008) identified five types of crowd (casual, cohesive, expressive, aggressive and explosive) ranging in the level of impact that they may elicit on an event and its audience. Similarly, Canetti (1973) identified six crowd types (invisible, bating, fleeing, prohibition, reversal and feast) and also used visual imagery to identify three main crowd symbols whereby he likened crowd movement to; the sea (dense and ever moving), fire (volatile with the ability to spread, destroy and behave expectedly), and the river (behavioural origins are taken more seriously than the goals). Building on this, Berlonghi (1995) identified a series of eleven crowd types. These ranged in their behavioural characteristics and the level of impact that they had on an audience. Core themes emerge across these typologies, which demonstrate a set of key behavioural profiles. Thus, it could be argued that crowd typologies must be understood by event managers to enable them to fully grasp the distinct profiles exemplified by common crowd types. It is also key for managers to understand how these profiles are influenced and the level of perceived risk that they denote in relation to the safety of those at an event in order to develop effective management strategies for such issues.

Table 45-1 Contents of the DIM-ICE Risk Model

<i>NORMAL</i>	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Design	Elements of the design that influence the crowd during ingress. this specifically relates to the elements of the design (such as barriers, local geometry, width of routes, paths and stairs, entrances, turnstiles, etc.	Elements of the design that influence the crowd during circulation (this relates to “mid-event”. moving around) such as route widths, stairs, layout and facilities management, concessions, etc.	Elements of the design that influence the crowd during egress (getting out). specifically the egress capacity, route complexity and geometry (stairs, corridors, doors, gates, etc.)
Information	Prior to the event a lot of things can influence the crowd behaviour such as advanced notifications, media coverage, tickets and posters, local knowledge, previous event history, nature of band, weather forecasts. Assess how the information prior to the event, near the event, on the way to the event and at the venue could influence the crowd, specifically signage and information systems.	Mid-event there could be a lot of conflicting information, the performance, the concessions, signage, PA announcements, stewards, information points. Assess how this influences the crowds and how best to inform the crowd of the facilities.	Signage and PA announcements for departure (non-emergencies) influence not only the direction but the distribution of the crowd. Ensure that all routes are clearly signed, checking for lines of sight to ensure all exit routes are visible.
Management	Stewards, security and police management can divert the crowd to the most appropriate areas, but they also influence the crowd's behaviour (such as reducing the element of hooliganism by increasing the visibility of police. this is also information). Queues can be actively managed and evenly distributed if approach routes allow good sight lines.	During the event, the stewards can actively manage queues and crowd movements.	During egress departing crowds can be actively managed = specifically car parks can be made more efficient if actively managed (rather than allowing a free-for-all dash for the exit).

(Continued)

Table 45-1 (Continued) Contents of the DIM-ICE Risk Model

EMERGENCY	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Design	How does the ingress system cope during an emergency? You may need to consider a “stay out” strategy and assess how the design copes with turning the crowd back from (say) an internal threat.	Mid-event how quickly can this site evacuate. This is typically the type of calculation a fire/safety officer would perform to ensure the site had sufficient egress routes and capacity for clearance.	How does the egress system cope during an emergency. You may need to consider a “stay put” strategy and assess how the design copes with holding the crowd back from (say) an external threat.
Information	During ingress how would the crowds be informed of an emergency? What type of information, in what form and content is required?	Mid-event how would the crowds be informed of an emergency? What type of information, in what form and what content is required? Ensuring the crowd moves away from the threat requires more than just a “please leave” announcement.	During egress how would the crowds be informed of an emergency? What type of information, in what form and content is required? For this you need to consider the crowd in the process of normal egress.
Management	During ingress, there may be more people trying to gain entry than is physically possible (for example a “free” event). The crowds may need ACTIVE management to prevent overcrowding in the event space. This would be considered an emergency as there is a risk of crushing if the event does not have an active management system.	During the event, the crowd may need to be managed (directed) away from threat. Consider the information (above) and the management of the egress for direction that ensures the crowd moves as quickly as possible AWAY from the source of danger.	The crowd may need to be managed AFTER evacuation (say on a holding area) to be kept safe until the threat/danger has passed. You may need to keep managing the crowd for several hours during a holding operation. You will need to keep the crowd informed until it is safe to let the crowd disperse.

As already indicated, crowd behaviours can arguably be influenced by audience profiles and collective characteristics in a positive or negative way. It may also be said that threat to safety in crowded spaces can be impacted by a broad range of catalysts. For example, expressive or revelling crowds (Berlonghi 1995) are often formed due to stimuli including event activities, performers' actions and the psychosocial factors of attendees. These can influence the audiences' experience in a typically positive way. The contributions of the experience economy and service design culminating in successful audience experiences are well documented in event management literature (Berridge, 2007; Hoffman et al., 2009; Mudie & Pirrie, 2006; Pine & Gilmore, 1999 & 2011; Rutherford-Silvers, 2008) and an expressive crowd is arguably an outcome of this approach. In such cases the event setting is designed to stimulate the senses and prompt specific behaviours with a desired effect creating feelings of positivity and revelry among the audience members.

It could also be argued that cohesive, spectator and participatory crowds, which are characteristics that straddle several of the common typologies, can also influence the audiences' experience in a positive manner.

Looking specifically at participatory crowds (Berlonghi, 1995), those engaged in running a marathon without incident are most likely to feel a sense of goal accomplishment and camaraderie resulting from taking part (Raj et al., 2009) and connecting them to the expressive crowd type (Rutherford-Silvers, 2008). That said, when security, social and man-made disaster factors (Berlonghi, 1995) combine in the form of terrorism threats at high profile events such as the Boston Marathon (BBC, 2012), the resulting outcome on the audience and the participatory crowd experience is undoubtedly extremely negative, which can influence a crowd to exhibit fearful behaviours. This links to the fleeing crowd type identified by Canetti (1973) presenting a high risk to safety.

There are a range of crowd types such as casual, thrill-seeker and political crowds (Berlonghi, 1995; Canetti, 1973; Rutherford-Silvers, 2008) that can produce positive behavioural outcomes but have the potential to evoke negative behaviour if managed inappropriately, triggered by either dissatisfaction or harm to the audience. Whilst demonstrator (political) crowds can produce positive shared experiences for the audience involved, catalysts such as police and security factors, and specifically, the use of excessive or unreasonable force can result in negative demonstrator behaviour, which can escalate to a more dangerous bating crowd (Canetti, 1973); this could be seen during the University of Birmingham Tuition Fee and Staff Wage Protest in January 2014, whereby a group of protestors who felt that they had been contained or "kettled" by police for four hours turned violent and were arrested on suspicion of assault and criminal damage (BBC Online, 2014).

Finally, the most negative and damaging crowd types to audience safety are deviant crowds which are potentially aggressive and hostile, rushing and

looting, or violent and explosive, and also more cautious and fearful crowds which can generate crowd issues such as escaping and trampling and dense and suffocating incidents due to their need to avert risk and flee (Berlonghi, 1995; Canetti, 1973; Rutherford-Silvers, 2008). Whilst some crowd situations can be pre-meditatedly deviant such as the actions of football hooligans, those taking drugs and criminals engaged in opportunistic theft, with behavioural patterns influenced by factors including escapism, anonymity, tolerant attitudes and sometimes marketing (Brunt & Brophy, 2004), this is not always the case and some deviant crowd situations do not always start out in this manner. One example of this is the sensation-seeking individual (Lepp & Gibson, 2007) characterised by motives of escapism in relieving frustrations and boredom, novelty, stimulation, disinhibition and boredom susceptibility (triggered by restlessness) which can become involved in negative and potentially deviant behaviours when this would arguably not have been their primary intention. Thus, those with a thrill-seeking profile may become deviant due to group identity and conformity (Postmes & Spears, 1998) or perhaps external catalysts within the event setting itself such as performer provocation or event activities and operational circumstances (Berlonghi, 1995) rather than other motivators.

It could be argued that there are links between the thrill-seeking and deviant crowd types and Torgersen's "Impulsives" and "Hedonists" personality profiles (Hochwalder, 2009; Vollrath & Torgersen, 2002). Key common characteristics include that these individuals are often pleasure-oriented, undependable, attention-seeking, and in need of social confirmation, with little control over his or her emotional reactions, and appearing chaotic and changing. Equally, links can be made between the cautious crowd and Torgersen's "Insecure", "Brooder" and "Complicated" personality types (Hochwalder, 2009; Vollrath & Torgersen, 2002), where common shared traits include being self-conscious, dependent on others, overly sensitive to his or her own mental and physical experience, emotionally intense experiences with occasional outbursts, as well as being overly careful, orderly, shy, withdrawn and with a tendency to give up easily in certain situations. It would therefore seem that inherent personality characteristics can also play a part in influencing crowd behaviour.

What is frequently documented in the literature related to deviant and cautious crowd types is that the prevalence of these two very different, but equally negative categories often attract negative media attention for the event associated with them and can typically result in fear, harm or fatalities to the event crowd in attendance. One of the most documented outcomes of crowd-related incidents is the trample disaster, which can be caused by a range of catalysts. These include poor planning on ingress and egress. One example of this is the 2010 Love Parade stampede (BBC News Online, 2010); other examples may be caused by unexpected weather events such as the Indiana State Fair stage collapse (Tuohy & Ritchie, 2012). The aroused emotions amid the audience at the Pearl Jam and Roskilde Festivals

(Shone & Parry, 2004) caused a similar type of behaviour and there are many and varied examples of this. Zen et al. (2008) researched trample disasters by using the case study of an unrestricted, un-ticketed outdoor Chinese cultural celebration. In this study large crowd gathered on a bridge to watch the celebrations; this resulted in a crowd crush and a resultant bridge collapse. The study concluded that in most trampling incidents, asphyxiation is the main cause of death resulting from the crowd “leaning” force (when people lean forward or push on those in front) leading to suffocation rather than “trampling” as is often portrayed in the media. Trample disasters may occur due to a range of factors which include as venue failings (e.g., fires, capacity issues), equipment failings, weather events and security issues (Berlonghi, 1995), which in turn elicit panic in the crowd and may be exacerbated by alcohol or drugs (Tarlow, 2002). Crowd panic is linked to emotional arousal theory (Borch, 2013) and the resulting crush is the cause of many trample disaster fatalities.

Conversely, however, it could be argued that a strong social identity amongst those in a dense crowd, where similar situational norms and a shared bond with one another, makes people more tolerant of a crowded situation. This owes its origins to those in the crowd perceiving this type of emotion to lower the risk to their personal safety and thus preventing them from exercising due caution. Often in such situations it is too late to act, and this outcome can be a contributing factor to the severity of the incident in highly dense and dangerous crowding incidents. This characteristic was noted in research by Alnabulsi and Drury (2014) around the effect of crowd density on safety at the Hajj, whereby though increasing levels of crowd density indeed reduced feelings of safety, this effect was moderated by the identification with the mass crowd and perceptions that others identified as Muslim.

As well as the more event-specific catalysts described above, links between crowd incidents and internal crowd warning signs (Tarlow, 2002) and also external destination-specific contributing factors (Abbott & Geddie, 2001) should be considered in the debate around crowd catalysts. According to Tarlow (2002) internally, the behaviour patterns of fan groups or followers can be considered alongside the prevalence of drugs and alcohol and a deviant, hedonistic party-fuelled atmosphere. Moreover externally, Abbot and Geddie (2001) suggest that event managers must consider the demographics of the host venue population, and the level of crime associated with the destination or venue in order to truly manage crowd incidents, although the two in many cases may not be related.

Thus, as Berlonghi (1995, p. 242) stated, “disasters and many of the less serious problems associated with them will continue to occur if we prepare only for ‘a large number of people gathered closely together’”. Stott and Reicher (1998, p. 509) conducted research with police officers that showed that, despite a perception of crowd composition as heterogeneous, officers perceived crowd dynamics in a more classical light involving an anti-social minority seeking to exploit the mindlessness of ordinary people in the mass;

police treating crowds in disorder as a homogeneous whole was argued to play an important role in escalating (if not initiating) collective conflict and was found to be a key component of social change in crowd contexts. Despite this call for concern almost 20 years ago, there is recent evidence to suggest that modern day policing strategies still prepare for undifferentiated methods and use of force when policing crowds and events (Hoggett & Stott, 2010; Stott et al., 2008). It is a holistic preparation delivery which is important in the context of crowds where both internal and external factors must be integrated to ensure that as many bases as possible are covered to mitigate against a disaster in a crowded space.

To conclude, whilst it has been established that crowds contain multiple personalities, the typologies and catalysts discussed in this paper are not only based on behaviour resulting from event-specific situations and scenarios but are also impacted by environmental ones and unique intrinsic behavioural patterns. These are borne out of a range of personal factors such as subculture and perceived norms. The challenges that exist for event managers relate to the manner in which crowd profile information is utilised in the management of risk and how this informs crowd management strategies.

REFERENCES

- Abbott, J.L. & Geddie, M.W. (2001). Event and Venue Management: Minimising Liability Through Effective Crowd Management Techniques. *Event Management*. 6. 259–270.
- Alnabulsi, H. & Drury, J. (2014). Social Identification Moderates the Effect of Crowd Density on Safety at the Hajj. *PNAS*. 111(25). 9091–9096. [Online] Available at: www.pnas.org/cgi/doi/10.1073/pnas.1404953111 [Accessed 12 May 2015]
- BBC News Online (2010). Stampede at German Love Parade Festival Kills 19. [Online] Available at: <http://www.bbc.co.uk/news/world-europe-10753399> [Accessed 10 Feb. 2014]
- BBC News Online (2014). University of Birmingham Protest: Thirteen Arrested. BBC News Online: Birmingham and Black Country. 30th January 2014. [Online] Available at: <http://www.bbc.co.uk/news/uk-england-birmingham-25955224> [Accessed 08 Feb. 2014]
- Berlonghi, A. E. (1995). Understanding and Planning for Different Spectator Crowds. *Safety Science*. 18. 239–247.
- Berridge, G. (2007). *Events Design and Experience*. Oxford: Butterworth-Heinemann.
- Borch, C. (2013). Crowd Theory and the Management of Crowds: A Controversial Relationship. *Current Sociology*. 1–18. [Online]. Available at: <http://csi.sagepub.com/content/early/2013/07/10/0011392113486443> [Accessed 18 July 2013]
- Brunt, P. & Brophy, K. (2004). English Seaside Resorts & the Deviant Tourist. *Acta Turistica*. 16(1). 1–30.
- Canetti, E. (1973). *Crowds and Power*. London: Penguin Books. Translated by Carol Stewart.

- Hochwalder, J. (2009). Burnout among Torgersen's Eight Personality Types. *Social Behaviour and Personality: An International Journal*. [Online] Available at: <http://www.highbeam.com/doc/1G1-208133816.html> [Accessed 02 Sep. 2013]
- Hoffman, K. D., Bateson, J. E. G., Wood, E. H., & Kenyon, A. J. (2009). *Services Marketing: Concepts, Strategies and Cases*. United Kingdom: South Western Cengage Learning.
- Hoggett, J. & Stott, C. (2010). Crowd psychology, public order police training and the policing of football crowds. *Policing: An International Journal of Police Strategies and Management*. 33(2). 218–235.
- Kemp, C., Hill, I., Upton, M., & Hamilton, M. (2007). *Case Studies in Crowd Management*. Cambridge: Entertainment Technology Press, Ltd.
- Lepp, A. & Gibson, H. (2008). Sensation seeking and tourism: Tourist role, perception of risk and destination choice. *Tourism Management*. 29. 740–750.
- Mudie, P. & Pirrie, A. (2006). *Services Marketing Management* (3rd edition). Oxford: Butterworth-Heinemann.
- Pine, J. & Gilmore, J. (1999). *The Experience Economy: Work is Theatre and Every Business is a Stage*. Cambridge, MA: Harvard Business School Press.
- Pine, J. & Gilmore, J. (2011). *The Experience Economy*. Updated Edition. USA: Harvard Business School Publishing.
- Postmes, T. & Spears, R. (1998). Deindividuation and Antinormative Behaviour: A Meta-analysis. *Psychological Bulletin*. 123 (3). 238–259.
- Raj, R., Walters, P. & Rashid, T. (2009). *Events Management: An Integrated and Practical Approach*. London: SAGE Publications.
- Rutherford-Silvers, J. (2008). *Risk Management for Meetings and Events*. Oxon: Routledge.
- Stott, C., Livingstone, A. & Hoggett, J. (2008). Policing football crowds in England and Wales: A Model of Good Practice? *Policing and Society*. 18(3). 258–281.
- Stott, C. & Reicher, S. (1998). Crowd action as intergroup process: introducing the police perspective. *European Journal of Social Psychology*. 28. 509–529.
- Tarlow, P. (2002). *Event Risk Management and Safety*. New York: John Wiley.
- Tuohy, J. & Ritchie, C. (2012). Indiana Stage Collapse Caused by Improper Construction. *The Indianapolis Star*: USA Today.com. [Online]. Available at: <http://usatoday30.usatoday.com/news/nation/story/2012-04-12/indiana-state-fair-stage-collapse/54231792/1> [Accessed 10 October 2013]
- Vollrath, M. & Torgersen, S. (2002). Who Takes Health Risks? A Probe into Eight Personality Types. *Personality and Individual Differences*. 32 (7). 1185–1197.
- Wakefield, J (2013). Can Technology Help Avoid Stampedes? BBC News, Technology. [Online] Available at: <http://www.bbc.co.uk/news/technology-24463736> [Accessed 24 October 2013]
- Zhen, W., Mao, L. & Yuan, Z. (2008). Analysis of Trample Disaster and a Case Study – Mihong Bridge Fatality in China in 2004. *Safety Science*. 46. 1255–1270.

Tristan Taylor – crowd safety and risk analysis in Australia

About Tristan

Tristan Taylor is a Production Manager at the Sydney Opera House, Australia. He has worked at the UNESCO listed venue for close to a decade and has had the pleasure of working with various art forms, venues, numerous talented company's, within and without the walls of this world architectural wonder.

Previous work includes Overlay Management for stadium Australia at the AFC Asian Cup 2015, Lighting team member at The Royal Opera House, Covent Garden, teaching theatre technology at the Hanoi Academy of Theatre and Cinema in Vietnam and numerous technical theatre engagements within Australia including Glen Street Theatre, Sydney Theatre Company, Ensemble Theatre and Company B among others.

Tristan Taylor is a Graduate from Deakin with a Graduate Diploma Arts and Entertainment Management and a Bachelor of Creative Arts – Theatre Technology from Wollongong University.

Introduction

The development and use of the crowd safety and risk analysis theories and applications within the events environment is making a cultural shift in the overall levels of safety when staging events in New South Wales and Australia. These developments have been initiated through law, regulations and the analysis of previous disasters. The work previously restricted to structural safety of items now has been supplemented and improved with the use of crowd analysis which has enabled event professionals to obtain a better understanding of a crowd dynamics and expected crowd outcomes. Risk analysis is now culturally embedded in event organisations as a standard way of conducting business. The continued development of the Crowd safety and risk analysis will help educate future event management in the correct use of tools, proactive crowd control rather than reactive control systems and continued vigilance on safety standards from slipping into the dangerous area of complacency.

Law

Legislative and law framework that live events works within in Australia is varied from state to state. While there is now a national commonwealth body called Safe Work Australia it is important to note that this body does not regulate or enforce the acts and policy as this is the individual state and territory's jurisdiction. Safe Work Australia has been established under the commonwealth Safe Work Australia Act 2008 to develop policy and workers compensation arrangements across the diverse state and territories of Australia. It is this body's goal, through a national approach, to improve the Health and Safety.

The state of New South Wales is governed by the NSW legislative act and regulations, Work Health and Safety Act 2011 and the Work Health and Safety Regulation 2011. These documents are the primary resource in Work Health and Safety in the workplace in NSW. Supporting, complementary and running concurrently to these two documents are the various Codes of Practise (now harmonised with the National Work Health and safety Legislation), National Construction Code – NCC (with NSW amendments) and Industry Guidelines.

Guidelines

The primary guideline for Australian entertainment industry in New South Wales could be argued is the Safety Guidelines for the Entertainment Industry (2001) issued by Live Performance Australia and the Media and Entrainment Alliance. This document unfortunately does not mention any crowd management even though supposedly covering safety in outdoor and indoor events. The industry guidelines currently being used for live events in NSW are sourced from other states; Crowd Control at Venues and Events (2007 Worksafe Victoria), Guidelines for Concerts, Events and Organised Gatherings (2009 Department of Health, Western Australia) or overseas resources: The Event Safety Guide (Second Edition) (1999 Health and Safety Executive, UK) or The Event Safety Guide (Event Safety Alliance, USA). It is important to note that due to legal precedence Australia will look to the United Kingdom before the United States for supporting documents due to the similarities of the legal systems.

Under the NSW Work Health and Safety Act 2011 and the Work Health and Safety Regulation 2011 the person Conducting a Business or Undertaking (PCBU) is required to give the highest level of safety and protection from hazards arising from work or the workplace as reasonably practicable. This is recommended to be discharged by utilising a Risk analysis approach to Hazard or Risk and the industry guidelines help directly with practical direction (Standards Australia 2009). These guidelines are still just that, guidelines, as all events should be considered unique, and this is reinforced by the risk analysis assessments required.

History and lessons learnt

It will come as no surprise that a major driving force behind the continued development of Crowd safety and risk analysis has been the tragedies of past failed events and gatherings. These tragedies can be seen as clear change points in the history of the safety literature, standards and regulations for the various countries in the world (Still, 2013, Upton, 2004). The UK had the misfortune to have the Hillsborough Disaster 1989 which resulted in the deaths of 96 people and injuries to 766 others (Taylor Report, 1989).

"Events of the magnitude of Hillsborough don't usually happen just for one single reason, nor is it usually possible to pin the blame on one single scapegoat..."

... Disasters happen because a whole series of mistakes, misjudgements and mischances happen to come together in a deadly combination."

Dr John Habgood, Archbishop of York, preaching at the Hillsborough Memorial Service on 23 April 1989 Taylor Report – Interim (1989).

In 1964, Estadio Nacional was the site of one of the worst stadium football match disasters in history, which happened during a Peru vs Argentina international. When the referee cancelled a goal towards the end of the match, riots broke out, which led to the police firing tear gas into the stands. The resulting stampede and locked exit gates resulted in the death of over 328 fans, but this may be an underestimation due to the unconfirmed deaths by gunfire and political situation in the country at the time (Edwards, 2014).

The United States had the Indiana State Fair Collapse 2011 (Witt Associates, 2012) which resulted in 7 deaths and over 40 injuries and although this disaster was related to structure the subsequent analysis of the event has spurred the event industry to look at safety at events as whole.

Australia has unfortunately not escaped tragedy with the death at the festival "Big Day Out" in 2001. While this pales in comparison to the history and continued disasters that have or are occurring around the world it is a pivotal point for Australia's event management of crowds. The attitude of "it can't happen here" was shown to be proven incorrect and some fundamental misunderstandings of crowd dynamics were shown to be held by the organisers of the event (Weir, 2002). While there is much discussion on how this tragedy has improved safety in the industry it must be noted that the recommendations of the coroner have largely been left to individuals to implement (Teague, 2012). The Love Parade 2010 (Germany) disaster caused the death of 21 people, with at least 500 others injured but in a reflection of misunderstanding of crowd science and management in Australia, it has been assumed by some that a disaster of this nature could not occur here due to the large numbers of the parade and the varied Australian venue conditions (Feeney, 2010).

Risk analysis

Risk analysis is an important tool for the planning of events and crowd management. The use of the correct tools for crowd management and the understanding of the limitations of standard risk assessments is an area where work is required (Upton, 2004). The Australian standard AS/NZS ISO 31000:2009

Risk management

The principles and guidelines are the base requirement for any work conducted in an event in Australia. It is designed to prompt the user into anticipating, understanding and evaluating the risks involved in any part of an organisation.

The application of this one size fits all analysis has at times ended with a theoretically correct document but potentially unrelated to reality of the

event (Still, 2014). It is essential that other tools also to be utilised and applied alongside the standard Risk Assessment when analysing a crowd attending events. Analysis tools such as RAMP Analysis (Route, Areas, Movement and Profile), Risk Mapping, Event Profiling, Decision Support Analysis, DIM-ICE Meta-Modelling (Design, Information, Management – Ingress, Circulation, Egress) help to examine, extract and communicate to the organisation the risks of any event (Still, 2014). These tools enable proactive safety analysis on the event before it occurs and allow an organisation to be prepared for the worst-case scenario and hopefully put in place systems or physical alterations that remove the risk highlighted.

Reactive plans vs proactive plans

In conclusion to the brief outline of Crowd safety and risk analysis in Australia, it can be seen that there is still a level of complacency within the industry (Teague, 2012). The industry has been regulated by the broader safety push in workplace reforms with more focus on risk assessments, compliance and the enforced accountability of companies and individuals. What is lacking is a pre-emptive system for the safety for crowds involved in entertainment and gatherings, the essence of the term crowd management. The industry is still heavily reliant on incident reactive systems that require an accident or tragedy to occur before action is taken. This need not be the course taken, a fairly low-level search of material on Crowd safety and risk analysis will divulge a wealth of free and accessible tools and systems that will take organisations from the back foot to the front foot in delivering a safe environment for events to occur.

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 behaviour. Crowd safety and risk analysis of events will have benefits across the organisation running the event. Ramp analysis can show when patrons arrive, and pressure will occur at the ticket and bag checks. Demographics will be beneficial to the food and beverage team, so they are able to work out when and where there will be a rush on the bar for food or drinks. Are the nearby bars a factor of when people arrive? What day of the week is the event on and where are the patrons coming from to arrive at the event? All of these questions can be broken down into simple and understandable analysis that allows management of an event to plan, execute and deliver the correct crowd management plans and in doing so deliver a safer and more enjoyable event for all.

REFERENCES

- Drury, J., Cocking, C., & Reicher S. (2008). Everyone for Themselves? A Comparative Study of Crowd Solidarity among Emergency Survivors. *British Journal of Social Psychology*.

- Edwards, P. (2014). Lima 1964: The World's Worst Stadium Disaster BBC Sport, Lima. <http://www.bbc.com/news/magazine-27540668>
 - Feeney, K. (2010) Crowd Crush Won't Happen Here: Splendour organisers - Sydney Morning Herald, July 28 2010. <http://www.smh.com.au/entertainment/crowd-crush-wont-happen-heresplendour-organisers-20100727-10u64.html>
 - Fruin, J. (1993). The Causes and Prevention of Crowd Disasters. In Smith, R.A. & Dickie, J.F., Engineering for Crowd Safety. Amsterdam: Elsevier Science Publishers BV.
 - Still, K. (2000). Crowd Dynamics. PhD Thesis presented to the University of Warwick, 2000.
 - Still, K. (2013). Introduction to Crowd Science. CRC Press.
 - Still, K. (2014). Visualising Risk Assessment for Crowd Safety, Journal of the International Centre for Sports Security. 2(1).
 - Thompson, G. (1993) Safety in Live Performance, Focal Press
 - Thompson, G. (2013). Sugarland Insurer Files New Lawsuit in Indiana State Fair Stage Collapse. The Boot.
 - Taylor, Lord Justice (1989). The Hillsborough Stadium Disaster Inquiry Interim Report. London: HMSO.
 - Teague, M. (2012) Durst Still Angry at Big Day Out Over Teen's Death The Vine. February 28 2012. <http://www.smh.com.au/entertainment/music/durst-still-angry-at-big-day-out-over-teens-death-20120228-1u07t.html>
 - Upton, M. (2004), Risk Analysis for Major Concert Events, The Benefit of Hindsight, Presented to Cabinet Office 'Seminar Safety at Mass Crowd Events'
 - Witt Associates (2012) An Independent Assessment of the August 13, 2011 Indiana State Fair Collapse Incident.
 - Weir, I. (2002) Findings and Recommendations by the Coronial Inquest into the Death of Jessica Michalik. Venue & Event Management Services Pty Ltd (Sydney, Australia)
- Government or Guidelines:
- Australian Entertainment Industry Association (AEIA) and the Media Entertainment and Arts Alliance (MEAA). (2001) Safety Guidelines for the Entertainment Industry 2001.
 - Department of Health Western Australia (2004) Guidelines for Concerts, Events and Organised Gatherings
 - Health and Safety Executive [HSE] (1999) The Event Safety Guide: A Guide to Health, Safety and Welfare at Music and Similar Events (2nd ed.). Surrey: HSE Books.
 - Health and Safety Executive [HSE] (2008) Guide to Safety at Sports Grounds. Surrey: HSE Books.
 - New South Wales Government (2011) Work Health and Safety Act 2011 (WHS Act) No. 10
 - New South Wales Government (2011) Work Health and Safety Regulation 2011
 - Standards Australia (2009) AS/NZS ISO 31000:2009 Risk management—Principles and guidelines
 - Safe Work Australia. (2008). Safe Work Australia Act 2008, No. 84, 2009 as amended, SafeWork Victoria. (2006). Advice for Managing Major Events Safely, Victorian Workcover Authority.
 - SafeWork Victoria. (2006). Crowd Control for Venues and Events: A Practical Occupational Health and Safety Guide, Victorian Workcover Authority.

Marc Tubee – crowd science in Holland

About Marc

Marc started at the age of 17 his education on the Police academy of the Netherlands to become a senior constable. He finished this study in 2012 and worked several years patrolling and responding to emergency calls.

Just a year after he left the Police academy, Marc started besides his job the study “Integrated safety and security management” on the applied university of science in ‘s-Hertogenbosch, the Netherlands. After three years, Marc followed in the short course “Crowd Safety and Risk Analysis”, taught by Professor Doctor G. Keith Still. After the course, Marc applied and started in 2016 the MSc “Crowd Safety and Risk Analysis” at the Manchester Metropolitan University.

Meanwhile Marc became a lieutenant in the Dutch Police force. He is advisor in major and special events to local authorities. During major events, he is commander and responsible for the total Police force present. Furthermore, Marc is assistant public prosecutor and commander on scene at large incidents and accidents.

At the time of writing this paper, he was a senior constable at The National Police of the Netherlands, Limburg District, Weert Frontline Team I work for the National Police of the Netherlands since 2008. As senior constable I respond to emergency calls. I also work as advisor for Events. He gave advice to the city of Weert, the city of Nederweert and the city of Leudal. He also gave advice about the event plans, the security and about the requirements the city needs to adhere to in order to acquire the legal permissions to organise an event.

For his frontline team he created plans for officers and staff what to expect and what to do in different scenarios. He also assesses how many officers need to be assigned to the event. Safety meetings with the Fire Department, health organisations, the city and organisers are held. he provided input to make events safe.

Marc started “Tubee Consulting” in which he combines his crowd management experience and knowledge with his daily job at the Police and thereby advises large events in Europe. His team is specialised in crowd watching while bodycams sent a live video stream towards the control room, helping commanders to make decisions based on live information. At different events, he worked in several responsible positions in safety and security. Marc uses the combination of public and private work to give training about his experience and knowledge.

What is crowd science

Crowd science is focused on the dynamics and density of the crowd and the behaviour of people within it. Still (2013) states that an understanding of and the ability to evaluate the spectrum of risks associated with crowds in public places is extremely important, as is the need to apply engineering standards and solutions to the process (Still, 2013).

Crowd density is the study of how and where crowds form and move. It is important for those working with crowds to understand the dynamics of them, how crowds understand and interpret information systems, how management systems affect crowd behaviour and how, where, when and why accidents occur (Still, 2013).

The application of mathematics can be utilised to identify if the capacity of an area is sufficient enough for the people you expect to be housed in it. One should also examine the psychological effects on the crowd. According to Still (2013) a crowd is a collection of individuals. We cannot for certain know what an individual is thinking or how their mood may shape their behaviour (Still, 2013). One tries to influence the mood and behaviour by the way in which the event area is engineered. Facilitating the decision-making process of individuals in the crowd is crucial to the way in which the event unfolds.

Crowd density is one of the most important aspects of crowd science. If the crowd density is too high, or in some cases too low the possibility of a crowd disaster is increased. One needs to create an event space large enough or a crowd small enough to always enable safe movement. This is directly related to ingress and egress gate size as well as the structures within the space.

At a critical high density (6 or 7 persons per m^2) the individuals in the crowd become a mass governed by generic movements within the mass. The crowd becomes susceptible to shockwaves which can result in serious injuries caused by too many people in a space or too few people, caused by the opening up of gaps in the crowd during a shock wave (Still, 2015). According to the Green Guide, 4 or 7 people per square metre is the maximum density on a stadium event site (47 people per 10 square metres of average-sized people (Still, 2013)). At events where families are attending, and a high number of strollers are anticipated, the number of persons allowed in a specific space must be reduced. This is also useful when dealing with young children at events where more space is needed per person.

The flow rate (crowd movement) is also an important concept in Crowd science. Free movement during ingress and egress is important and the development of ingress and egress rates in advance of an act can support the hypothesis leading to a higher or lower audience than anticipated which is fully dependent on the way in which the crowd is expected to move, ingress, egress and fill the space. How freely people move and how fast can they circulate or leave the event area in a normal, or emergency situation, is crucial to the planning phase of an event. Mathematics can be used to predict the most appropriate flow rates for the egress, but one needs to consider many other factors including the behaviour of the crowd.

Crowd science is also based on how to make places a safer place for crowds. The event organiser is responsible for the safety of those attending their event. How the event site is constructed will have an influence on the safety of the crowd. Also, the decisions made by the management team will affect the safety of the event.

Risk assessment methodology

What is often found is that new event organisations do not have enough knowledge on how to create a safe event. Many safety plans are rudimentary in their development and describe a range of generic actions in relation to a safe event space. Often profit is regarded as a higher priority than safety. In the uneducated this is understandable, but those starting such events must be quickly made aware of their responsibilities.

The modelling of crowds supports those delivering events and enables the management team to understand the main aspects of crowd movement and dynamics thus creating a safer environment.

Still (2013) says that crowd disasters mostly occur owing to issues with either the design, the information or the management of the event.

Design: This area focuses on the construction of the event? It clarifies the expectations regarding the site and the number of people in which the event can safely operate. Questions which must be asked include “is it clear where we expect the most people at different times?” and “is the area big enough to house the event?” When a crowd disaster occurs, it is often related to the fact that the design of the event area is not based on the optimum capacity or crowd flow rates.

Information: One can influence the behaviour of the crowd by providing them with information in the correct way. The information that one provides, must be clear and understandable for all attendees. Incidents where the information provided was not clear or was incorrect has resulted in members of the crowd making poor decisions and endangering the lives of themselves and/or others.

Management: The event management team is responsible before, during and after the event in relation to a range of activities including the information delivered and the design of the event itself.

DIM (Design – Information – Management) is related to the three phases of an Event:

Ingress: Visitors enter the event area

Circulation: The visitors move over the area during the event

Egress: Visitors leave the event area

The DIM-ICE risk model is a concept which organisers of an event should take heed. It is a template that can be used for event planning focusing on

the time-related element of crowded space risks. It is a universal template which can be applied to any event. By using the model, crowd management teams would have a heightened awareness of the different phases during normal and emergency phases. The utilisation of the model affords an overview of the risks of the event using a traffic light matrix.

The DIM-ICE risk model is not the only modelling technique for crowd risk analysis and safety engineering. The RAMP analysis is another technique. RAMP focuses on:

Routes: Which focus on the way in which the crowds move towards, migrate through and leave the event site. They are drawn on maps, plans or site diagrams to assist the visualisation of the crowd's movement.

Areas: Are the locations of differing crowd density within the footprint of the site. This also refers to the capacity of each section of the event site and can provide both a numerical value and a capacity.

Movement: Is the rate of passage through the various parts of the event system. For example, the rate at which the crowd is processed through a ticket or search area.

People/Profile: Relates to the behaviour of the crowd and includes elements such as the age/demographic, mix (male/female ratio), intelligence from other shows and any other intelligence that may assist in the management of the crowd (Still, 2013).

Using the RAMP will give the event manager the opportunity to identify problems and challenges early in the event process so that plans can be changed and accidents hopefully prevented.

A decision support analysis will help the event manager to make crucial decisions related to the management of the event. Crowd modelling helps to identify possible issues and challenges related to the crowd flow and thus these can be identified early, and systems put in place to alleviate them during the build of a venue or during the ingress, circulation and egress at an event.

All of these models can be applied in real time and support the development of a safer event. One such example is a meta model used to identify potential crowd congestion at an event in Holland. In this example identifies the effect that the weather would have had on an event location.

In addition to these models one can also use Fruin's FIST model.

Force: Crowd forces can reach levels that are unmanageable. At high levels those at an event may be severely injured or die owing to compressive asphyxia. Such forces are due to many idiosyncratic crowd movements including the domino effect (Fruin, 1993). In event engineering one needs to consider the risks of the force. For example, using single, dual or triple barriers at events depending on their capacity, crowd profile and preponderance to anti-social behaviours in the crowd.

Information: This includes both internal and external communication as well as verbal and non-verbal delivery.

Time: This area relates to the time taken to ingress and egress the site as well as circulation. Often the timing of the event and the micro planning of the stages can cause issues where the crowd has unexpected surges and quiet points, and these have to be carefully managed. Understanding crowd movements through time enables you to base your strategy on a series of key points which can alleviate issues on the day owing to the planning and management of time and crowd flow.

Using models will give you a representative view of the reality. You may be able to predict what will happen at an event and how you can put practices in place to alleviate as much risk as possible. “If you can predict it, you can prevent it”! (Still, 2015)

Official documents – legal environment

In the Netherlands there are no legal precedents that identify what the event organiser needs to put in place to keep the event safe. Last year the “Evenementenhandboekveiligheid” (Event Safety guide) foundation was established. The goal of this organisation is to create standardised rules to provide “safe events”. The event guide is to be based on the UK’s Purple Guide. The Purple Guide defines the criteria for pop concerts and similar events (Still, 2000).

At the present time, when the government requests advice for the licensing of an event, the Fire Department ascertains the number of emergency exits that there are in the venue and their widths. The space is then calculated which in turn enables them to calculate the capacity. This calculation and advice are based on the BRIS Bouwbesluit 2012 (Building Act 2012) article 2.108, related to the capacity of an emergency route:

- c. 90 people per meter clear width of a passage, if the passage of a double door or similar movable structural part is with a maximum opening angle of less than 135 degrees.
- d. 110 people per meter clear width of a passage if the passage is a single door or similar movable element of design is with a maximum opening angle of less than 135 degree
- e. 135 people per meter clear width of another passage.

There are many calculations that do not use Fruin’s 82 people per metre per minute rule. Many of these have utilised numbers which do not scale down a value correctly and do not identify the complexity, congestion possibilities and human factors. However, many of those who have worked in this area for many years have carried out their own calculations and over time have created numbers which have worked for them. Although Fruin’s work does compute in many circumstances there are areas where the experiential learning of the teams involved, and painstaking work has created numbers which do work in such situations in specific venues.

The European standard was replaced in April 2014. The new standard gives a description relating to new conditions for spectator safety in facilities. The NEN-EN 13200-7 norm describes spectator facilities and their entry and exit elements and routes. This categorically states that 82 people per metre per minute can move through an exit with no encumbrance under controlled circumstances on level ground.

NEN standards include specifications and rules defining the requirements that a product, process or service must fulfil. The standards are not law, but they are “best practices” for voluntarily use (NEN, 2016).

Sheila Russell – defining crowd science

About Sheila

Sheila Russell is an experienced Event Safety Consultant with over a decade of experience working in the field of event safety, project management and education in both the public and private sectors.

Prior to launching Safer Events by Design Ltd in 2016, Sheila worked for Capita as an Event Safety Consultant, producing risk assessments, emergency plans and providing crowd management consultancy services for several clients.

As part of the Last Mile Operations team, Sheila was responsible for ensuring crowd safety on ingress and egress to the Olympic Park for the Olympics and Para Olympics 2012 and worked as Crowd Management Consultant to stages of the Tour de Yorkshire and Tour de France.

Sheila currently produces risk assessments, provides event related safety advice as in engaged as Event safety officer for several large sporting and music events with crowd capacities ranging from 2000–70,000 in various locations across the UK including large stadium events, city centre and greenfield sites.

Sheila's main area of interest lies in utilising crowd science techniques alongside site planning tools to create the optimum experience for event audiences; creating not only a safe environment but helping to create an event site that works as well as it can in terms of crowd flow, logical layout and efficient use of space. This can only be achieved when the event audience demographics, event site and thorough knowledge of how the audience will interact and use the site are clearly understood and combined with crowd science techniques.

Sheila has also previously worked in the field of education and was a Lecture in Event Management in Higher education for several years. She holds a Diploma in Crowd Science and Risk Analysis, a Diploma in Event Safety and Postgraduate Certificate in Event Management

Introduction

This paper will consider the meaning of Crowd safety and risk analysis and will further discuss a range of key theories underpinning this subject area. The paper will draw on examples of some of the explored theories that have been researched across the globe and will conclude by discussing the application of these theories in the design, planning and delivery of events to improve crowd safety and increase the overall experience of the crowd. “Crowd science” is a term that is often used within the events industry but has many and varied connotations depending on the capacity to understand the theoretical and practical applications of it and the role and knowledge of the person using the term. It is primarily linked to the study of crowd-related incidents at events and focuses on the causes of these incidents and

how they can be prevented through the application of various techniques, some of which will be discussed in this paper.

There are several theories, research studies, techniques and tools that have been researched, created and applied to the events industry. Some are rooted in psychology; some are mathematical in nature and others are a combination of disciplines providing a dual paradigm approach.

The first theory discussed in this paper is based on the psychology of the crowd and research into how that crowd will move and react under different conditions depending on the nature of the leadership within the crowd. Early research suggested that an individual loses the ability to make their own judgements within the crowd and may act in a way that they would not normally. This can cause “mob behaviour” through a collective mentality and the individuals concerned losing the ability to make rational decisions. There are a number of theoretical approaches that base their research on this premise, and these go as far back as the 19th century (Gustavo le Bon, Gabriel Tarde, William MacDougall). Later research (Pelechano & Badler, Sime) suggests that within a crowd different personality types influence the ultimate crowd movement as a whole and that the dominant or “leader” types ultimately decide on the direction and decisions that the crowd makes, as a collective decision.

Some theories and approaches rely on mathematical techniques and modelling that can support our understanding of crowd density, flow rates and other crowd phenomena such as shockwaves and crowd collapse. Other researchers have combined human psychology and mathematical modelling techniques and applied this to events to try to provide an understanding of and avoid major crowd incidents through the analysis of past crowd disasters. Fruin, a specialist in pedestrian traffic analysis and building circulation system design, has extensively researched crowd dynamics and identified four elements that can be considered in any event. “Fundamentally, there are four interacting elements in every crowd situation: time, space, information, and energy” (Fruin, 1984). Each of these elements overlaps and all have to be considered to some extent when exploring the dynamics of the crowd.

Sime (1995) stresses the need to factor in the same elements in creating the most accurate and likely outcomes of a range of elements related to crowd science. There is also the need to validate computer simulations of crowd movement and escape behaviour against psychological as well as engineering criteria as through such exploration new knowledge can be ascertained. Through their recent research into crowd behaviour based on heuristics, Moussaid et al. (2011, p. 82) identifies that “Understanding pedestrian heuristics and the emergence of complex crowd behaviour is a crucial step toward a more reliable description and prediction of pedestrian flows in real-life situations”. This heuristics-based model has important practical role to play in such research, for example, the improvement of architectures and exit routes, as well as aspects of the organization of mass events.

Ultimately crowd science is a combination of various techniques and theories that assist the reader in the understanding of the dynamics of a crowd under different conditions. However, most importantly, a knowledge of crowd science can help to improve the safety of a crowd and the quality of the experience therein through the application of improved site design, information management and event delivery as well as contingency planning. Such theories, techniques and modelling tools can provide those working with crowds with tools and/or “modelling techniques” which can be applied practically within the events industry. This originates at the planning stage where a combination of psychology, design and mathematical modelling can be used. Supporting this, the application of flow rates, risk assessments, the calculation of adequate safe ingress and egress and the ensuring that maximum capacities and evacuation rates are calculated (Green Guide 5th edition, *The Event Safety Guide* 2014), and maintenance may be required to ensure that a safe event takes place. Ultimately the control of crowd density is crucial in the prevention of fatalities. Shockwaves may occur once the density of the crowd reaches 6–7 people per square metre and at this point independent movement within a crowd may no longer be possible and fatalities have occurred in crowded spaces through crushing and asphyxiation. The UK Guide to Safety at Sports Grounds advises “no more than 47 people in 10 metres for a standing crowd and no more than four people per 10 square metres for a moving crowd” to try to event this issue.

It is not necessary to have specialist software to apply these techniques and this can be carried out through the analysis of various factors within an event including crowd demographics, topography, climate/weather, the type of event, transport, arrival profiles and timeframes and the simple application of tools such as DIM-ICE, RAMP (Routes, Areas, Movement and Profile - Still, 2013, p. 122). Through the use of these models, it becomes possible to make an event site safer during the ingress, circulation and egress time frames. These models combined with considered steward briefings used to relay this information to those working at the event will support the understanding and essential knowledge of those working on an event. Design, information, communication and management are key in the avoidance of major crowd-related issues and under emergency conditions it is of utmost importance that all staff are well informed and are able to communicate the relevant information required to the crowd to avoid the risk of crowd related issues. Sime (1995) applies a simple equation similar to Fruin to this process “(A) design and engineering×(B) communications technology×(C) crowd management×(D) crowd behaviour and movement”.

All of these factors are interlinked – i.e., the design of an event site must provide adequate ingress and egress supported by a well-planned infrastructure within which to operate. During egress there is a need for tried and tested signage/wayfinding and those working must have knowledge and ability to communicate under pressure. The management team will need a framework and process through which they can communicate the

key decisions to their staff. If the management structure is sound and the event design has been well executed but the information is poor, there is a potential for crowd-related issues to take place throughout the event. Thus, all aspects of the systems, frameworks and structures related to the event must be able to stand up to scrutiny at any time during the event. Where the signage is poor and the knowledge of those working at the event lacks focus delays in the decision-making processes can be caused which may in some cases be fatal in a situation such as emergency egress situation.

Pelechano and Badler's research informs us that "decision skills in emergency situations are influenced by several factors such as environmental complexity, dynamically changing situations, and time pressure"; therefore clarity of information and communication is vital as well as the design of an event space. This event space should be designed to enable the most efficient means of egress from any point on an event site.

The information provided to the security company and stewards working at the event is vital in supporting them in their understanding of the nature of the event and providing the company with information about the site, taking them through the event arrival profile and providing clear maps and diagrams of the areas in question.

This is important as it enables staff to gain an overview of the event and a clear understanding of what to expect, where to expect it and when to expect it and thus they can plan accordingly. Risk mapping can be used as a visual tool (most people also respond well to visual learning and are far more able to remember the information when it is presented in this format than if presented verbally for example) which highlights the key areas and times of crowd activity. As Sime's work points out, in a crisis, the only sense which works as the time frame collapses is that of visual acuity, the other senses cannot be relied on for information processing. There will be occasions where the unlikely and unforeseen will happen but in a well-planned, well-designed event with well-informed staff the potential to deal effectively with a crowd related incident is greatly improved and risk minimised throughout. A number of research studies (Moussaid, Milazzo, Nicholson & Roebuck, Pelechano and Badler, Sime et. al.) have made it clear that during emergency egress a crowd will look for the nearest available exit from the event site. However other research has identified that between 75% and 80% of those entering a site or venue will leave by the same gate of door that they entered through. On a well-planned site, with clear signage, a crowd can clearly see the nearest available exit and can decide to move towards it should they not be moving towards the main entrance where they entered and know the escape route back to their mode of transport. Confusing or poor wayfinding information reduces the possibilities of escape and can lead to pockets of panic and the potential of crowd crushing.

To conclude, there are many schools of thought and many approaches that can be taken to crowd science. However, from a safety practitioner's perspective all research in this area have its place and have contributed to a

more rounded understanding of why crowd disasters occur. Research into this area has provided us with a range of tools to enable us to be more adept in the prevention of crowd issues. Without an understanding of crowd science by those managing an event and its impact on the strategic, tactical and operation delivery of the event, those engaged in the safety of the crowd are leaving themselves open to further crowd issues. Events which should provide a pleasurable experience can do the opposite and in the most extreme circumstances can be dangerous. Not only has the research in crowd science helped us to prevent disasters it can also help us to make the event experience much more pleasant by the improvement of event site layouts, ingress and egress possibilities, transport links, signage and queuing times. The role of crowd science in the future of events is incredibly important for public safety and improving the customer experience and application of these tools and techniques can easily be incorporated into the event planning process.

REFERENCES

- Berlonghi, A. E. (1995). Understanding and Planning for Different Spectator Crowds. *Safety Science*. 18. 239–247.
- Dickie, J. F. (1995). Major Crowd Catastrophes. *Safety Science*. 18. 309–320.
- Fruin, J. (1987). *Pedestrian Planning and Design* (2nd ed.). Elevator World, Mobile AL.
- Marana et al., “Estimating Crowd Density With Minkowski Fractal Dimension”
- Marana, A. N., Velastin, S. A., Costa, L. da F., and Lotufo, R. A. (1998). Automatic Estimation of Crowd Density Using Texture. *Safety Science*. 28(3). 165–175.
- Moussaid et al. How Simple Rules Determine Pedestrian Behaviour and Crowd Disasters. Clark University 2011. Available at: www.pnas.org [Accessed 10 Mar. 2015]
- Milazzo II, J. S. (1996). The Effect of Pedestrians on the Capacity of Signalized Intersections. Master’s Thesis, North Carolina State University, Raleigh.
- Nicholson, C. E. & Roebuck, B. (1995). The Investigation of the Hillsborough disaster by the Health and Safety Executive. *Safety Science*. 18. 249–259.
- Pelechano and Badler. Modelling Crowd and Trained Leader Behavior during Building Evacuation. University of Pennsylvania, pg 1
- Sime, J. D. (1995). *Crowd Psychology and Engineering*. Elsevier.
- Still, G. K. (2013). *Introduction to Crowd Science*. CRC Press
- The Event Safety Guide (2014) HSE.
- UK Guide to Safety at Sports Grounds (2008)

Andrew Seeds – crowd science

About Andrew

Andrew⁷ is Events Broadcast Engineer turned Safety Advisor who has worked on events and filming projects large and small. A strong believer in the utilisation of data driven approaches to risk management, he is currently studying his MSC in Crowd Safety & Risk Analysis with Manchester Metropolitan University. Generally Seen on his Bicycle both around event sites and for leisure.

Introduction

Humans are by Nature Social Animals; we have some of the most complex relationship structures on the planet between friends, family and acquaintances. The Global human population is now more than 7.5 billion people; however, it is commonly popularised (but academically disputed, Bryner, 2012) that the principle of six degrees of separation exists between any two random people on the planet.

Humans, therefore, like to get together on mass to share experiences and information. The act of people gathering on mass is generally referred to as a “crowd”. This essay will discuss key elements of Crowd science, its application with permitting and licensing and the legislative framework that the fields operate in.

What is crowd science?

Various terms have been used to describe the systematic study of crowds, all with slight differences:

Crowd behaviour: Also referred to as crowd psychology/mob theory/collective behaviour; “kinds of activities engaged in by sizable but loosely organised groups of people. Episodes of collective behaviour tend to be quite spontaneous, resulting from an experience shared by the members of the group that engenders a sense of common interest and identity” (J. Smelser et al., 2000).

Crowd dynamics: The study of how and where crowds form and move above the critical density of more than one person per square metre (Still, 2013).

Crowd risk analysis: The use of a systematic technique to evaluate the risks posed by a crowd in each situation.

Crowd science: Crowd science is a more recent term that has been coined, which encompasses the scope of all the above into an umbrella term for ease; K Still in 2014 broadly defined crowd science as Crowd Modelling, Monitoring and Management.

⁷ <https://www.linkedin.com/in/andrewseeds/>

As a rule, crowd science is used to develop safer (thus better) crowd management plans. It is closely linked to the topics of emergency preparedness and evacuation modelling as well as Health and Safety.

Key theories

There are many coexisting theories within the spectrum of crowd science, which are reflective of the interdisciplinary and multifaceted nature of the field of study.

Fruin – level of service

This is a widely cited theory that shows that Crowd density (people per square metre) and crowd flow (people per metre per minute) are related (Fruin, 1971).

Fruin – causes and prevention of crowd disasters

This introduces a systematic approach (FIST model) to crowd disasters and also outlines some of the factors which can be influenced in event management (Fruin 2003).

Fruin – crowd dynamics

Originally worked upon with a primary function of auditoriums, this work also gives a good level of underpinning to the interacting elements within crowds (Fruin, 1984).

Convergence theory

The concept that a crowd will take on the form and focus of an existing group of persons and that people wishing to join this existing group will choose to join the prevailing mind set (wiseGEEK, 2019).

De-individualisation theory

This suggests that “Individuals in public places generally carry out continual self-assessment of their behaviour to ensure compliance with social norms. However, when an individual becomes part of a crowd, they become anonymous and lose their individualised sense of identity, thus loosening their normal inhibitions” (tutor2u, 2019).

Legal framework

Within the UK the Health and Safety at Work, etc., Act 1974 (Parliament, 1974) is the umbrella legislation which unpins Health and Safety Legislation.

Two key sections of the act concerning Crowd science are as follows: Section 4 “General duties of persons concerned with premises to persons other than their employees” which places obligations on the person(s) who are in control of premises to ensure the “all means of access thereto or egress therefrom available ... is or are safe and without risks to health”.

Section 3 of this act also places obligations on employers to ensure that “so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety”.

Various other specific acts cover the topic in specific areas including but not limited to the “Safety of Sports Grounds Act 1975” or the “Fire Safety and Safety of Places of Sport Act 1987”.

The legislative framework does by its nature tend not to give specific pointers instead focusing on broad duties. There are however multiple “quasi-legal” (not legislative themselves however likely to be referred to as best practice in the event of a prosecution) documents and standards which are used as best practice guidelines within the industry and also quite commonly adopted as requirements to meet as part of any licensing processes an event may undertake. This is particularly pertinent within sports grounds with their requirement to have a safety certificate as part of their licencing process. A brief outline of some of these is stated below:

Guide to Safety at Sports Grounds published by the Sports Ground Safety Authority commonly known as the “The Green Guide”

“Managing Crowds Safely” – A guide for organisers at events and venues published by the HSE; this is also known as HSG154

The Purple Guide to Health, Safety and Welfare at Music and Other Events – An online portal of advice and information which was based on the of the previous HSE publication HSG195

Integration of crowd science within the licensing/permitting process

Within the UK, the most stringent legislation and degree of required oversight concerning Crowd Safety would generally be regards to Sports Grounds with capacities over 10,000 persons. The governance is formed from the Safety of Sports Grounds Act 1975 which in turn was implementing the guidance of the Wheatley Committee, established in the wake of the 1971 Ibrox Stadium Disaster (Parliament, 1973). Here local authorities (Councils) are required to establish the safety capacity of a sports ground and issue a ‘Safety Certificate’ for the ground. This safety certificate allows councils to place conditions on the safe use of the ground as required. This is in addition to the licensing process required for activities such as alcohol provision/amplified music required under the licensing act.

Other venues, such as concert halls, street food markets and greenfield sites, do have a level of oversight through the licensing process (which does generally state the licenced capacity); however, this is usually more focused on fulfilling the licensing objects set out by the licensing act 2003, which while including “public safety” as a driver, do not require the application to be as thoroughly scrutinised for “crowd safety” elements.

A potential weakness for the oversight provided by local authorities when it comes to crowd safety is that each authority is largely autonomous, which leads to wide-ranging changes in standards between authorities depending on the level of specific knowledge and expertise of the council team appointed to oversee the application. This is in comparison to the existence of the Sports Grounds Safety Authority which the government-funded body that oversees local authorities on the specific regard of spectator safety at sporting events as well as acts as a central licence issuer for significant sporting stadiums within England and Wales. This central “body of expert knowledge” means that there is likely to be more widespread commonality across the level of oversight provided. To the knowledge of the author, no government body exists in the same way for the wider events sector.

Another area where large crowds occur is during demonstrations and protests; here there can be very limited to no oversight of the protest especially if there is no marching element of the protest as there is no requirement to let the police know (GOV.UK, 2019). As such there could be no oversight of large numbers of people gathering.

It is often stated that legislation is not the answer to everything and that the implementation of legislation can often stifle creative freedom and technological development. However, the basic requirements for a competent person with respect to crowd safety have successfully been applied across the sports sector as such it would not be unreasonable to suggest the widening of spectrum would not be a logical next step; this has already occurred once prior after the Bradford Football stadium fire the definition of sports ground was changed (Fire Brigades Union, 2019).

Event planning

When working in a defined space such as an existing building or venue, it would be expected that venue capacity is a key consideration when planning an event. Thus, it would be expected that all venue operators and owners would be fully aware of the capacity of their venues and the need to safely manage the crowds of people attending events. While in most well-established venues this is the case; it is noted anecdotally by the author that in many cases the advertised capacity of the space is simply not achievable safely or in some cases within the licence restrictions for the venue. Recent case law has established that there is a lack of understanding amongst event stakeholders about the importance of establishing capacity (Rychlikova, 2019).

The ability to safely manage the number of persons expected within the venue at all times should be a key driver when establishing the capacity for any event. It is however noted that often commercial pressures are a key factor in capacity with venues looking to maximise revenue from increased attendance.

Event delivery

During the event delivery process, especially for small to medium events, there is often a disconnect between the security team and the safety team (especially if the same organization is responsible for Occupational Health and Safety for the event also) and it should be clear that strong two-way lines of communication should exist and be direct. Reports and studies into crowd science note the importance of competent and trained personnel within the event management team and structure, and the wider this reaches the more proactive that the sector will be. One of the main advantages of applying crowd science techniques within the delivery phase of an event is that it removes a large proportion of the emotive nature of the decision making involved and gives a systematic, supported and justifiable decision-making structure.

Risk Assessment methodologies (and their application to crowd safety)

The HSE is the governmental body responsible for the enforcement of the Health and Safety at Work Act; they define risk assessment on their website as “Think about what might cause harm to people in your workplace and decide whether you are taking reasonable steps to prevent or control that harm” (HSE, 2019). There is no set design for a risk assessments; however, the process is well established through HSG65 (HSE, 2019) as “Think about Hazards, Look at who might be harmed and how, Decide how you will control the risks, Record your findings”.

The HSE also provides a template on what a risk assessment could look like, and while the specifics vary, the table format is extremely common and widely accepted. Still argues in his 2014 article that this encourages “over-estimating risk” and also generally carried out as a “paperwork exercise” however notes that the largest weakness is because, through its condensed nature, the person reading the assessment does not have enough information to address the issues (Still, 2014).

Another potential way to carry out a risk assessment, especially on smaller or repeating projects, is for a discussion to be undertaken between the event management team, potentially however not exclusively during a site walkaround. While this leads to a potentially high level of information sharing, it is largely informal and potentially undocumented whilst also potentially not following a consistent structure which may allow key elements to be overlooked completely. Its lack of evidence is also another potential weakness.

It does, however, have advantages in its simplicity and speed of implementation which suit it to small-scale reactive changes being made quickly by people who have a high level of competence within a wide range of sectors.

Within the same article Still proposes two overlapping methods of risk assessment, RAMP analysis (a systematic approach analysing the: Routes travelled/available, Areas in use, Movement and Profile of the crowd) and also the use of visual aids to demonstrate the findings. A key factor proposed by Still is the inclusion of different phases/times of an event within the findings to show the differing risk hotspots as they change throughout the event (for example from the security search area at the beginning of a concert to the stage area during the event itself but then also to the exits routes during egress).

REFERENCES

- Bryner, J. (2012). *Six Degrees of Separation: Fact or Fiction?* [online] livescience.com. Available at: <https://www.livescience.com/32340-six-degrees-of-separation-fact-or-fiction.html> [Accessed 13 Aug. 2019].
- Fruin, J. (1971). *Crowds - Levels of Service*. [online] Gkstill.com. Available at: <http://www.gkstill.com/Support/crowd-flow/fruin/LoS.html> [Accessed 13 Aug. 2019].
- Guide to Safety at Sports Grounds. (2018). 6th ed. Sports Ground Safety Authority.
- HSE. (2019). *Risk Assessment: How to do a Risk Assessment*. [online] Available at: <http://www.hse.gov.uk/simple-health-safety/risk/how-to-do-a-risk-assessment.htm> [Accessed 13 Aug. 2019].
- HSE. (2019). *Managing for Health and safety (HSG65)*. [online] Available at: <http://www.hse.gov.uk/pubns/books/hsg65.htm> [Accessed 13 Aug. 2019].
- HSG154 Managing Crowds Safely - A Guide for Organisers at Events and Venues. (2019). 1st ed. London: HSE.
- Fruin, J. (1984). *Crowd Dynamics and Auditorium Management*. [online] Gkstill.com. Available at: <http://www.gkstill.com/Support/crowd-flow/fruin/Fruin3.html> [Accessed 13 Aug. 2019].
- Fruin, J. (1993). *Fruin - Causes and Prevention of Crowd Disasters*. [online] Gkstill.com. Available at: <http://www.gkstill.com/Support/crowd-flow/fruin/Fruin2.html> [Accessed 13 Aug. 2019].
- Smelser, J. N., Killan, L. M., & Turner, H. R. (2000). *Collective behaviour | psychology*. [online] Encyclopaedia Britannica. Available at: <https://www.britannica.com/science/collective-behaviour> [Accessed 13 Aug. 2019].
- Legislation.gov.uk. (1975). *Safety of Sports Grounds Act 1975*. [online] Available at: <https://www.legislation.gov.uk/ukpga/1975/52/enacted> [Accessed 13 Aug. 2019].
- Legislation.gov.uk. (2019). *Fire Safety and Safety of Places of Sport Act 1987*. [online] Available at: <https://www.legislation.gov.uk/ukpga/1987/27> [Accessed 13 Aug. 2019].
- Legislation.gov.uk. (2019). *Health and Safety at Work etc. Act 1974*. [online] Available at: <https://www.legislation.gov.uk/ukpga/1974/37> [Accessed 13 Aug. 2019].
- Parliament. (1973). *Crowd Safety at Sports Grounds*. [online] Available at: <https://api.parliament.uk/historic-hansard/lords/1973/jan/24/crowd-safety-at-sports-grounds> [Accessed 13 Aug. 2019].

- Parliament. (2003). *Licensing Act 2003*. [online] Available at: <https://www.legislation.gov.uk/ukpga/2003/17/introduction> [Accessed 13 Aug. 2019]
- Rychlikova, M. (2019). *Fire Risk at York Nightclub 'Too Awful to Contemplate'*. [online] York Press. Available at: <https://www.yorkpress.co.uk/news/17722589. overcrowding-at-kuda-nightclub-created-risk-too-awful-to-contemplate/> [Accessed 13 Aug. 2019].
- Sports Grounds Safety Authority. (2019). About the SGSA - Sports Grounds Safety Authority. [online] Available at: <https://sgsa.org.uk/about-the-sgsa/> [Accessed 13 Aug. 2019].
- Still, K. (2013). Crowd Dynamics. G. Keith Still BSc Physical Sciences (Robert Gordon's Institute of Technology, Aberdeen 1981) A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Mathematics. University of Warwick, Department of Mathematics.
- Thepurpleguide.co.uk. (2019). *The Purple Guide*. [online] Available at: <https://www.thepurpleguide.co.uk/> [Accessed 13 Aug. 2019].
- tutor2u. (2019). *Aggression: Deindividuation | Psychology | tutor2u*. [online] Available at: <https://www.tutor2u.net/psychology/reference/aggression-deindividuation> [Accessed 13 Aug. 2019].
- wiseGEEK. (2019). *What is Crowd Psychology?* [online] Available at: <https://www.wisegeek.com/what-is-crowd-psychology.htm> [Accessed 13 Aug. 2019].
- Fire Brigades Union. (2019). *Bradford City FC Stadium Fire*. [online] Available at: <https://www.fbu.org.uk/history/bradford-city-fc-stadium-fire> [Accessed 13 Aug. 2019].
- GOV.UK. (2019). *Protests and Marches: Letting the Police Know*. [online] Available at: <https://www.gov.uk/protests-and-marches-letting-the-police-know> [Accessed 13 Aug. 2019].

Shane Harris – crowd science – Australia

About Shane

Shane Harris is an event professional based in Perth Western Australia with 25 years' experience in venue management, Shane began working in stadiums and mass gathering events in 2010. Since that time, he has worked over 300 sporting and entertainment events with crowds up to 65,000. Having run events with various fixed and temporary infrastructure, a key component of Shane's work is the application of crowd science principles in planning and delivering events. Shane holds a Bachelor of Science, Master of Business Administration and completed his Level 5 certificate in Crowd Science in 2015.

Introduction

Current event planning techniques are based largely on legislative compliance and government guidelines. While they may be a useful starting point, a compliance approach is limited in application to effective crowd analysis and management planning due to the number of variables involved and established practices in event planning and risk assessment. Crowd science considers key crowd fundamentals and offers several applications aimed at improving crowd management and crowd risk analysis through considering variables influencing the crowd, over different phases of an event. The simple-to-apply and low-cost strategies offer a structured approach to enhancing crowd analysis and planning, thereby improving crowd safety.

In terms of mass gatherings, Crowd science identifies how and where crowds form, and considers the dynamics, density and behaviour of crowds. Crowd science takes a back-to-basics approach to undertake effective risk analysis for the design and management of mass gathering events (Still 2014). There are three key areas underpinning Crowd science: Crowd Density, Crowd Behaviour and Crowd Dynamics.

Crowd density

Crowd density is a measure of the number of people in a given area for a crowd (Pearl, 2015). Upton (2008) believes that controlling crowd density is the primary aim of crowd safety planning. This supported by Pearl (2015) who states that crowd density is the single most important predictor of crowd-related injuries. Events should be planned on the number of people expected rather than predetermined capacity (Helbing & Mukerji, 2012). While the commonly allocated crowd density of two persons per square metre is used to determine capacity, this approach fails to consider how the crowd will distribute themselves (Upton, 2004).

Since crowds do not fill a space evenly, (Challenger, Clegg & Robinson 2010; Still 2000) this approach fails to consider how crowd density can build in different areas of the event.

For a crowd in motion, high density flows are a primary cause of crushing disasters (Alnabulsi & Drury, 2014). Still (2014) has established that crowd densities of six to seven people per square metre are susceptible to shock-waves. At very high density individual control is lost as a person becomes an involuntary part of the mass (Fruin, 1993). Helbing et al. (2007) and Helbing, Johansson and Al- Abideen (2007a) identify dangers from transitions as the high-density crowd moves in a stop-and-go pattern creating turbulence.

Crowd behaviour

While crowd density has been identified as a leading contributor to crowd accidents, the importance of crowd behaviour cannot be underestimated. With human emotion involved, understanding the factors that influence crowd psychology and therefore behaviour becomes a critical factor in crowd safety (Raineri, 2004).

Crowd behaviour during concerts can range from hysteria to a classic rock culture which can create massive pressure loads through crowd movement (Upton, 2008). Promoters and entertainers use a mix of media to create hype during concerts to excite the mass so that it appears irrational (Raineri, 2004; HSE, 2000). Similarly, these aspects can also be used to reduce crowd excitement and therefore pressure (HSE, 2000).

In a high-density crowd, a lack of front to back communication is common (Fruin, 1993), with most people in a crowd not being able to see what is happening around them (Fruin, 1984). This is reinforced by Illiyas, Mani, Pradeepkumar and Mohan (2013) who advises that stampedes have been caused by a simple accident or even a rumour or competition can trigger a crowd disturbance.

The belief that crowds panic is a major source of crowd incidents is generally false, with little evidence to suggest that crowds panic or are prone to unreasonable behaviour (Challenger et al., 2010; Pearl, 2015). On the contrary, evidence suggests that crowds often exhibit positive cooperative behaviours (Alnabulsi & Drury, 2014), responding rationally to a perceived threat (Pearl, 2015). As asserted by Helbing and Mukerji (2012), people do not normally die because they panic and they panic due to the threat and perceived risk.

Crowd dynamics

Crowd dynamics involves the study of how and where crowds form and move above the critical density of more than one person per square metre (Still, 2000). It is about more than just figures, it also involves elements

or information management, risk assessment, psychology, emergency planning and spatial awareness (Pelling, 2009). Helbing and Mukerji (2012) cites that it is often not just crowd density alone that causes crush incidents but the dynamics that occur when the density is so high that physical interaction between people transfers forces which have a cumulative effect.

Crowd dynamics can be influenced by a number of factors. When the doors open for a General Admission show, competition for the best spot can cause a crush (Pearl 2015). An encore could make fans change direction, rushing back into an oncoming crowd (HSE 2000). People walking in groups of friends will alter the crowd flow compared to people by themselves or in pairs (Verbruggen, 2014). People taking shortcuts, using known routes or leaving the way they came will all alter crowd flows (HSE, 2000).

Regulatory requirements

The HSE Event Planning Guide (Purple Guide) is considered an international standard for event planning and provides guidance for a range of event planning practices (Earl et al., 2005; Aguila, 2010; Upton, 1995). Complimenting this are the Green Guide and Primrose Guide, which provide recommendations for building design and fire safety, respectively (Still 2000). Standards from these guides are duplicated in several reference documents in Australia (DOH, 2009; Safework Victoria, 2006). While these guides may not be a legislative or regulatory document, their inclusion in certificates and use by local regulators lends regulatory weight to their recommendations and standards (Still, 2000).

These guides are the result of several decades of research and provide useful information for the competent person (Still, 2000). However, these guidelines contain inconsistencies which can be misinterpreted and fail to consider several characteristics of crowd dynamics in their make-up. Further, Upton (2008) believes that some approaches are simplistic and fail to consider the range of variables included in mass crowd movements.

Building compliance

From a building compliance perspective, compliance with current guidelines and defined capacities does not mean that crowds within a venue cannot reach critical densities, especially as crowds move through smaller areas within a given space (Pearl, 2015). A flaw with the guides assumes that people will distribute themselves evenly through available space (Still, 2000). Further, many guidelines compliant spaces do not consider arrival behaviours (Still, 2000), impacts of corners and obstacles (HSE, 2000), bottlenecks and other space deficiencies (Pearl, 2015), all of these can have an impact on crowd flow performance and therefore crowd safety.

Risk assessments

Risk assessments are generally a legislative requirement for events (Upton, 2008; HSE, 2000) and needed to meet insurance requirements (Aguila, 2010). The traditional risk assessment was an engineer-designed system to meet political needs to act on health and safety legislation (Upton, 2008). The system multiplying likelihood and consequence to establish a numerical value is fundamentally flawed, overestimating risk and using cut and paste rather than true consideration (Still, 2014a). For crowd activity, personal bias means that this model of assessment is more opinion than science (Upton, 2008).

Earl et al. (2005) identifies that the quality of risk assessments in Australian Outdoor Music Festivals is lacking, with the Occupational Health and Safety document for a Big Day Out where a fatality was recorded bearing no resemblance to the appropriate standard, and not being completed for the event (Weir, 2002). Event managers in Australia fail to take a holistic approach to planning (Reid & Ritchie, 2011), with factors including costs, inadequate data, staff capacity and poor methodology all contributing to poor risk assessments (Earl et al., 2005). This is reinforced by findings from Wertheimer (1993) who identifies similar issues in American Rock Concerts. Further Upton (2004) believes that the quantitative approach utilised in risk assessment failed to consider behavioural issues, work conditions and other variables important in making accurate assessments.

Simulations and models

Computer simulations, one method of trying to assess crowd flows, are useful but do not provide a comprehensive solution to crowd management (Still, 2000). Challenger et al. (2010) identifies that a combination of macro and micro models offers the best results for accurately modelling crowd movement. However, modelling crowd movements in complex spaces involves a range of variables which may not be identified or understood (Still, 2007). Such simulations do not account for variables including individual and group behaviours (Shiwakoti et al., 2011), cultural factors influencing crowd behaviour (Kaminka, 2011) and individual's familiarity with their environment (Challenger et al., 2010). In addition to this, the cost of crowd simulation models and their effective use is cost-prohibitive for many event organisers (Still, 2014).

Given that the primary crowd management objective is to avoid critical densities and rapid group movements (Fruin, 1993), improved crowd planning is crucial to the event planning and risk assessment process. Crowd science applications offer an opportunity to improve these processes and overcome deficiencies previously identified. A key advantage of these applications is that they are simple to apply and low cost, making them readily available to event planners at all levels.

Upton (2008) advocates a risk assessment model that considers phases of arrival, attendance, egress and emergency considerations separately. DIMICE risk model provides this opportunity as it considers the primary influences on crowd behaviour (design, information and management), across three phases of an event (ingress, circulation and egress), for both normal and emergency modes (Still, 2014). By considering behavioural influences over key event timings, this model allows a more applied risk assessment process for crowd planning. Different design, communication and management requirements can be identified to allow for different strategies to be developed and employed. Colour coding the DIMICE tables allows for quick identification of risk profiles against each variable. Still (2014) risk modelling can be further applied for analysis of other risk types such as weather or attractions against established variables such as merchandise outlets or signing stations (Still, 2014).

RAMP (routes, areas, movement and profile) as described by Still (2014) is a further Crowd science tool that offers a structured approach to crowd planning. Using simple drawing techniques, the process improves the feel for the area and patron movement, allows layers of information to be built up and overlaid, and can be used to model different times of the event – ingress, circulation and egress (Still, 2014). The consideration of areas and movement profiles over time corresponds with Raineri and Earl's (2005) belief that of the need for time-based crowd management aimed at keeping flows below critical densities. Further, the inclusion of crowd profile in event planning corresponds with Raineri's (2004) assertion of the critical importance of crowd behaviour in the risk assessment process.

Traditional risk assessment and crowd planning have a number of shortfalls, contributing to crowd safety inadequacies. Crowd science improves event planning by offering low-cost applications that provide a structured approach to crowd and risk analysis, thus improving crowd safety.

REFERENCES

- Aguila, M. I. (2010). Security in Music Festivals and Concerts. Degree Thesis, HAAGAHHELIA, University of Applied Sciences.
- Alnabulsi, H. & Drury, J. (2014). Social Identification Moderates the Effect of Crowd Density on Safety at the Hajj. *PNAS*, **111**(25), 9091–9096.
- Challenger, R., Clegg, C. W., & Robinson, M. A. (2010). Understanding Crowd Behaviours (volume 1) Practical Guidance and Lessons Identified. London: The Stationary Office.
- Department of Health [DoH]. (2004). Guidelines for Concerts, Events and Organised Gatherings, Western Australia: DoH Publication.
- Earl, C., Parker, E.m & Capra, M. (2005). The Management of Crowds and Other Risks at Outdoor Music Festivals: A Review of the . *Environmental Health*. **5**(1). 37–49.

- Fruin, J. (1984). 'Crowd Dynamics and Auditorium Management' Auditorium News, May.
- Fruin, J. (1993). The Causes and Prevention of Crowd Disasters. In Smith, R.A. & Dickie, J.F., Engineering for Crowd Safety, Amsterdam: Elsevier Science Publishers BV.
- Dickie, J.F. (ed.) Engineering for Crowd Safety, Amsterdam: Elsevier Science Publishers BV.
- Health and Safety Executive [HSE]. (2000). Managing crowds safely" A guide for organisers at events and venues. Surrey: HSE Books.
- Helbing, D., Johansson, A. & Al-Abideen, H. Z. (2007). The Dynamics Of Crowd Disasters: An Empirical Study. *Physical Review E*. 75(4).
- Helbing, D., Johansson, A., & Al-Abideen, H. (2007a). Crowd Turbulence: The Physics of Crowd Disasters. In the Fifth International Conference on Nonlinear Mechanics (ICMN-V) (pp. 967–969). Shanghai.
- Helbing, D. & Mukerji, P. (2012). Crowd Disasters as Systemic Failures: Analysis of the Love Parade Disaster. *EPJ Data Science*. 1(7). Retrieved from <http://www.epjdatascience.com/content/1/1/7>.
- Illiyas, F., Mani, S., Pradeepkumar, A., & Mohan, K. (2013). Human Stampedes during Religious Festivals: A Comparative Review of Mass Gathering Emergencies in India. *International Journal of Disaster Risk Reduction*. 5(1). pp. 10–18.
- Kaminka, G. (2011). The Impact of Cultural Differences on Crowd Dynamics in Pedestrian and Evacuation Domains, Bar Ilan University.
- Pearl, T. H. (2015). 'Crowd Crush: How the Law Leaves American Crowds Unprotected. *Kentucky Law Journal*, Forthcoming. Retrieved from <http://ssrn.com/abstract=2569373>.
- Pelling, K. (2009). 'Safety in Numbers', ISquared, Summer, pp. 23–26.
- Raineri, A. (2004). The Causes and Prevention of Serious Crowd Injury and Fatalities at Live Music Festivals. 12th Annual Safety Institute of Australia Conference, Gold Coast, Queensland.
- Raineri, A. & Earl, C. (2005). Crowd Management for Outdoor Music Festivals. *Journal of Occupational Health and Safety*. 21(3). 205–215.
- Reid, S. & Ritchie, B. (2011). Risk Management: Event Managers' Attitudes, Beliefs, and Perceived Constraints. *Event Management*. 15. 329–341.
- SafeWork Victoria. (2006). Advice for Managing Major Events Safely, Victorian Workcover Authority.
- Shiwakoti, N., Sarvi, M., Rose, G., & Burd, M. (2011) 'Consequence of Turning Movements in Pedestrian Crowds During Emergency Egress', Transportation Research Record, no. 2234, pp. 97–104.
- Still, K. (2000). Crowd Dynamics. PhD Thesis, University of Warwick.
- Still, G. K. (2007). Review of Pedestrian and Evacuation Simulations. *International Journal of Critical Infrastructure*. 3(3/4). 376–388
- Still, G. K. (2014). Introduction to Crowd Science, Boca Raton, Florida, CRC Press.
- Still, G. K. (2014a). Visualising Risk Assessment for crowd safety. *International Centre for Sport Security Journal*. 2(1), 48–52.
- Upton, M. (1995). Incident at the Donington Monsters of Rock 1988. Paper presented to the Safety at Mass Crowd Events Seminar, UK Cabinet Office Emergency Planning College, December.

- Upton, M. (2004). Risk analysis for major concert events, the benefits of hindsight. Cabinet Office Seminar on Safety at Mass Crowd Events (January 2004), Chicago: Crowdsafe.com Library.
- Upton, M. (2008). 'Safe Event Management', Paper delivered to the Theatre Managers Association Conference, Birmingham, 10 June.
- Verbruggen, T. (2014). Maintaining Formations in High Density Crowds. Master's Thesis, Utrecht University.
- Weir, I. (2002). Findings and Recommendations by the Coronial Inquest into the Death of Jessica Michalik, Courtesy of Crowdsafe.com Library.
- Wertheimer, P. (1993). The American experience: rock concert safety. Chicago: Crowdsafe.com Library.

Eric Kant – introduction to crowd science

About Eric

Eric is the owner of Phase01⁸ Crowd Management, a crowd safety consultancy in the Netherlands. Eric specialises in managing crowds in confined spaces and crowded places. He graduated from Manchester Metropolitan University with a master's degree in Crowd Safety and Risk Analysis (Crowd Science). Furthermore, Eric is a qualified agent-based modeller, certified by Lund's University. He has worked with Prof Still on many crowd counting projects, around the world.

Eric specialises in the various strategies that should be prepared for the emergency evacuation of large crowds and the associated effective crowd communication strategies. He is pragmatic and takes an evidence-based approach.

Eric has years of experience as an event safety specialist at the Dutch National Police where he provides expert advice to operational, tactical, and strategic commanders during the approval phase, preparation, and operational phase of major or high-risk public events, crises and mono/multidisciplinary operations. He was involved in hundreds of mass events: from national celebrations, concerts, and Christmas markets to Premiere league soccer fixtures and EDM festivals.

Introduction

In modern society crowds, or large concentrations of people, occur frequently and without serious problems. However, with the growing number of large and increasingly larger events, the potential for incidents, accidents and mass fatalities is increasing. Crowd incidents, accidents and mass fatalities at large-scale events or places of public assembly are continuing to take place. To reduce the incidence of such events, one has to understand the crowd and its behaviour. Berlonghi (1995) argued that it is a serious mistake to underestimate the crowd and that one must understand the different types of crowds that occur, “without this understanding, we are left with random attempts at crowd control and crowd management which may result in serious losses of life, health, property and money”.

Crowd science

Crowd science can be described as the study of the underlying causes of crowd accidents and incidents (specifically mass fatalities in crowded spaces). The science is derived from the initial study on Crowd dynamics (Still, 2000) which he describes “as the study of the how and where crowds form and move above the critical density of more than one person per square metre” (Still, 2000).

⁸ <https://phase01.nl>

Key theories that underpin crowd science

Crowd dynamics can be described “as the study of the how and where crowds form and move above the critical density of more than one person per square metre” (Still 2000).

Crowd density can be defined as the number of people and/or objects in a given space (Drintewater and Gudjonsson, 1989). It is important to understand how and/or where crowds reach critical density and at what density there is a potential for a crowd crush. Fruin (1993) argues that a density of 7 persons or more per square metre is dangerous: “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”.

Crowd behaviour: Fruin (1993) argues that crowd behaviour falls into two general categories: a flight response or a craze. “Flight occurs where people experience either a real or perceived threat” and “a mass craze is a competitive rush to obtain some highly valued objective”.

Flow rates: Still (2000) argues that “in confined spaces, crowd dynamics is a function of the local geometry, and this effect can dominate the crowd flow and behaviour especially during emergency egress”.

Safety limits: Still (2000) states that “the effects of geometry (dead-ends, barriers, constriction in corridors and changes in corridor widths) create their own dynamic compressions in a moving crowd. We need to know the limits for safety and how close any particular environment is to those limits”.

Risk assessment

If one wants to prevent crowd incidents or accidents from taking place, one must identify risks and assess these risks in an assessment. Risk assessments are mandatory in most European countries; it is unclear however if proper risk assessments are always conducted when they should be.

In this example, in the Netherlands, the “conventional risk assessment” is the most used method to assess risks.

Conventional risk assessment process

In a conventional risk assessment user assigns a value to a defined risk and a value to severity. Users then multiply these values. The overall score indicates what action (a qualitative assessment) should be taken to control the risk.

The risk assessment example (Table 46/48) shows the risk “Person receives a minor injury”. The likelihood is 3 (possible) multiplied by severity 2 (minor) = Risk factor 6. According to the Risk Likelihood – Severity Matrix in Table 18 creates a risk with a “medium priority”.

If a person gets injured in a “non-crowded” space on an event site, the severity can be “minor”. However, the consequences of a person being injured

in the middle of a narrow, crowded corridor during an emergency evacuation are higher. Thus, the severity may change to “major” or “catastrophic” which would migrate the risk factor to one of “high priority” or “urgent action”.

One can also discuss the values that are given to risks and severity. If we invite three participants to assign such values, we will invariably attain three different outcomes as such outcomes are based on personal preference and perception.

One can deduct from this approach that conventional risk assessment does not promote the delivery of descriptive values. Users are forced to describe the apparent risk in a short and concise value judgement which can easily be misconstrued by others.

Still (2013, p. 139–142) describes this process as highly subjective and flawed because of the condensed description. He identifies that important information about the risks might be lost when decoded or translated into a risk management plan.

Still further argues (Still, 2013, p. 63) that the conventional risk assessment process is “fraught with the potential for misinterpretation and misrepresentation for two reasons. The first is that crowd risks are dynamic in nature and one number⁹ may not be sufficient to identify the risk and assign an appropriate outcome; the second is that in the risk assessment process, a list does not lend itself to description and hence the understanding of the dynamic nature of an event”.

This paper argues, in a conventional risk assessment, that risks are recorded as a single line sentence which is not sufficient for a full and frank understanding of the identified risk itself. Important information about the risk may be lost in translation or transference owing to the condensed nature of the format. The person/persons that has the task of converting these risks into a crowd management or operational plan may miss important details about the identified risk which may lead to a flawed plan. The conventional risk assessment does not lend itself to the recording of the dynamic nature of risks and neither to the recording of detailed information. Owing to these flaws it can be determined that the conventional risk assessment is not an appropriate method for assessing risks.

Appropriate risk assessment methodology

Crowd risks are dynamic in nature and may change over time. Crowd risks are related to location, duration and severity, meaning that the location of the risk can change over time from – for example – entrance gates to front of stage, that a risk can occur for just a short moment or for a long period and that severity can be different depending on many external factors or influences. Thus, a more appropriate methodology for determining risks as a fluid, dynamic assessment structure which changes dependent on those identifying, assessing and managing the risk at any given time.

⁹ A value that is assigned to a risk

Table 45-2 Conventional Numerical Risk Assessment

Likelihood	Severity
1 = Rare	1 = Insignificant
2 = Unlikely	2 = Minor
3 = Possible	3 = Moderate
4 = Likely	4 = Major
5 = Almost certain	5 = Catastrophic

Table 45-3 Risk Likelihood. Severity Matrix¹⁰

		Likelihood				
Severity		1	2	3	4	5
	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Table 46 Risk Assessment¹¹

Hazard	PERSONS AT RISK	Risk Factor	Measures	Responsible
Person receives a minor injury	All	$3 \times 2 = 6$	Ensure there are adequate qualified first aiders on site during the event	First Aid Site supervisor

Influences on crowd behaviour

During his Crowd Dynamics PhD research Still developed a database and began to categorise major crowd disasters. Still (Still, 2013, p. 78) “defined three fundamental elements that were common to major incidents:

1. Design-related issues, where there appears to have been a miscalculation relating to crowd flow and the space capacity.
2. Information-related issues, where there appears to have been an external influence on the crowd behaviour that induced an accident/incident.
3. Management-related issues, where there appears to have been one or more management decisions that were responsible for the accident/incident”.

Phases of crowd behaviour

We can break down an event in three primary phases:

1. Ingress, the crowd approaches the site or venue and passes the entry system.

¹⁰ Risk Likelihood–Severity Matrix as used at Dutch National Police, Regional Unit Rotterdam

¹¹ Risk assessment example taken from City of Unley (Australia) website

2. Circulation, where the crowd moves around at the site or venue.
3. Egress, where the crowd leaves the site or venue.

Modes of crowd behaviour

Finally, there are primarily two types of behaviour; these focus on how crowds will react: during normal or emergency situations.

DIM-ICE matrix

Still (Still 2013: 118) designed a template “that focusses the user’s attention on the time-related element of crowd risks”, “by structuring an event into times”. In the template, we can outline the influences (design, information and management) (DIM) against the phases (ingress, circulation and egress) (ICE) under normal and emergency situations.

Still (Still 2013: 120) argues that “the matrix approach not only focusses attention on key elements of time related risks” but that the model also “highlights what most crowd management plans fail to address: that incidents can occur during ingress, mid event and during egress”.

Table 21 is an example of DIM-ICE matrix. Colours can be applied to highlight the severity of the risk: Green = Low Risk, Amber = Moderate Risk, Red = High Risk. If we take a close look on the matrix, we see that there is an identified moderate risk in design during ingress: “*Limited routes/Congested spaces, no queuing design*”. It is obvious that this risk might become a high risk during an emergency (Figure 49).

As the DIM-ICE meta model is designed to outline the three key influences (design, information and management) against the key phases (ingress, circulation and egress) at normal or emergency, one can argue that this matrix approach has more information, in a more accessible format, than a conventional risk assessment.

Legal, regulatory and risk management framework

In the Netherlands, licensing officers from the fire department are responsible for the assessment of event emergency evacuation plans. For crowd flow these officers use the norms as defined in the Bouwbesluit 2012¹² article 2.108. Most important norm defined for evacuation is the capacity of an escape route or (emergency) exit, which is calculated at 90 persons per metre width per minute.

On April 1, 2014, the Dutch foundation NEN¹³ published the “NEN norm” NEN-EN 13200-7:2014: “Spectator facilities – Part 7: Entry and exit elements and routes” – this “specifies safety and design characteristics of entry and exit elements of passage that are used in spectator facilities, either singularly or in combination, to provide a route”. According to NEN, the flow capacity is not more than 82 persons per metre per minute: “The maximum rate of passage in a level passageway shall be taken as not more than 82 persons/m/min” (NEN-EN 13200-7:2014: 18). Despite this

¹² ‘Building act 2012’.

¹³ NEN supports the standardization process in The Netherlands.

new guidance, it is unclear if the licencing officers from all fire departments use it when assessing event evacuation plans. The problem with this guidance is that it has no legal basis for fire departments.

In the Netherlands, there are no official guidelines that define safe crowd densities. There are many documents available online (without any legal basis!) that nevertheless are used by several fire departments. These state that 2.5 person per square metre is the maximum density of a crowded space.

The Netherlands does not have the luxury of a “Green” or “Purple” guide, as is available in the United Kingdom. However, at the Dutch foundation “Stichting Evenementenhandboek”¹⁴ is reproducing and translating the Purple Guide for use in the Netherlands under Dutch conditions.

In the Netherlands there are three types of events identified: “Category A”: regular events; “Category B”: events that need attention; “Category C”: risky events. The distinction is made based on a “risk scan”. This comprises an excel worksheet with dozens of variables and calculations showing A, B or C (as identified above) when filled in. It is mandatory to conduct a risk assessment in a category C “risk event” case. As mentioned before, it is unclear if appropriate risk assessments are always conducted when they should be.

Crowd science and its application within the events scenario¹⁵

Currently there is a lack of appropriate knowledge in the field of crowd science. One tends to wait till something happens, learn from these mistakes,

Table 47 DIM-ICE Matrix Example¹⁵

Normal	Ingress	Circulation	Egress
Design	Limited routes, congested spaces, no queueing system	Limited routes, no queueing design	Limited routes, congested spaces, no queueing design
Information	Live screens, stewards	Routing towards areas and facilities, live screens	Live screens, stewards
Management	Progress monitoring procedures	Progress monitoring no protocol, chain of command	Progress monitoring no protocol, chain of command
Emergency	Ingress	Circulation	Egress
Design	Limited routes, congested spaces, no queueing system	Limited routes, no queueing design	Limited routes, congested spaces, no queueing design
Information	Megaphones, security, live screens, alarm, basic signage	No crowd congestions warning signs, measures	Megaphones, security, live screens, basic signage
Management	Progress monitoring procedures	Progress monitoring, chain of command	Overcrowding measuring is vague

¹⁴ <http://evenementenhandboek.nl>

¹⁵ Example DIM-ICE Matrix provided by Prof. GK Still at the short course Crowd Safety & Risk Analysis, November 2015, Utrecht - Holland.

or not, as the case may be then change procedures, guidance, laws and plans. It is important that all parties involved in the safety, planning and licensing process understand the nature of crowd risks. If not properly understood we are condemned to experience problems that are in fact predictable and thus avoidable.

To reduce risks and to prevent crowd incidents and accidents from happening, it is important to increase the awareness of this area and to invest in the training and education of those responsible for the identification, assessment, analysis and management.

REFERENCES

- Drintewater, J.A. & Gudjonsson, G.H. (1989). The Nature of Violence in Psychiatric Hospitals. In Howell, K.S. & Hollin, C.R., Clinical Approaches to Violence. Chichester: Wiley.
- Fruin, J. J. (1993). The Causes and Prevention of Crowd Disasters. Originally presented at the First International Conference on Engineering for Crowd Safety, London, England, March 1993. Revised exclusively for crowdsafe.com, January 2002.
- Still, K. (2000). Crowd Dynamics. PhD Thesis presented to the University of Warwick, 2000.
- Still, K. (2013). *Introduction to Crowd Science*. Boca Raton: CRC Press.
- Bouwbesluitⁱ (2012). Artikel 2.108. Capaciteit van een vluchtrouteⁱⁱ http://wetten.overheid.nl/BWBR0030461/Hoofdstuk2/Afdeling212/2121/Artikel2108/geldigheidsdatum_02-12-2015
- Wet Veiligheidsregio's (2010). Artikel 10: *Het inventariseren van risico's van branden, rampen en crisis*ⁱⁱⁱ <http://wetten.overheid.nl/BWBR0027466/>
- NEN (2014). NEN-EN 13200-7:2014: *Spectator facilities - Part 7: Entry and exit elements and routes*. <https://www.nen.nl/NEN-Shop-2/Standard/NENEN-1320072014-en.htm>

Graeme Clark – crowd safety and risk analysis

About Graeme

Born and raised in New Zealand I studied a Bachelor of Commerce at the University of Auckland prior to moving to Australia in 2003. I have spent the past 11 years living with my wife and raising a family (two kids aged 8 & 5) in Brisbane, Queensland and working for Stadiums Queensland, a statutory authority of the Queensland Government. Stadiums Queensland is charged with the management of major sports facilities declared under Queensland Government regulation as being venues having the capacity to stage national and international sports, recreational and entertainment events. Venues include the Brisbane Cricket Ground (The Gabba), Suncorp Stadium and the Queensland Sport and Athletics Centre (QSAC) that was built for the 1982 Commonwealth Games. As QSAC's Operations Manager I am intensively involved with the planning and implementation of major events including concerts and motor sport events that can have a capacity of up to 49,000 patrons. In recent years the venue has hosted AC/DC, Guns N' Roses and Monster Jam.

In 2015, I undertook the Level 5 Crowd Safety and Risk Analysis short course presented by Prof. Dr. G. Keith Still. I have since incorporated strategies from this course when planning for major events held at QSAC. By utilising a scientific approach, I understand better the way crowds behave at the venue and I can simply identify areas of risk that require additional controls. Further, I have been able to share my knowledge with colleagues and stakeholders and I consider that through a collective understanding of crowd dynamics the overall safety of patrons during events has been improved.

Essay – introduction

The development of crowds in society is unavoidable whether it is a crowd of attendees at a public gathering or entertainment event, a crowd of shoppers at a marketplace, a crowd participating in a protest or utilising public transport systems. The mass gathering of people is a daily occurrence. Combined with an increasing urbanised population demographic (United Nations, 2014), the existence of large-scale crowds is becoming more frequent. Fruin (1984) argues that public safety is determined by the interaction of the design of a space and efficient crowd management. If large concentrations of people are not properly planned for, managed and controlled serious consequences may occur.

This paper will discuss Crowd Science, the main theories underpinning it and how it is important in the planning of mass gatherings in modern society. The paper will address the traditional method of risk analysis within a regulatory framework and its inherent limitations. It will conclude by

outlining tools and models born out of the science that will enable event planners to better manage crowds and therefore design safer environments for mass gatherings.

What is crowd science?

Crowd science is the study of how crowds form, move and interact within the local geometry and can be broken down into three main components: crowd density, crowd behaviour and crowd dynamics.

Crowd density relates to the number of people within a space. As the density of a crowd increases the effects are significant. At high densities, there is a risk of serious injury. Fruin (1993) argued that at occupancies of about 7 people per square metre and above the crowd becomes a mass at which point shock waves can be generated that can propel people up to 3m in any given direction. At such high densities, the forces can be impossible to resist or control and it is possible that people may end up suffering from compressive asphyxia resulting in injury or death. The risk is heightened as it is becoming extremely difficult to gain access to casualties at such high crowd densities and therefore the provision of an appropriate and timely medical response is made virtually impossible. Oberhagemann (2012) observed that a crowd density of 4 people per square metre results in a rescue team moving at only 16 metres per minute. However, in many crowds the density is in pockets and movement through parts of the crowd may be relatively easy with only certain areas causing an issue.

Understanding the impacts of crowd density has prompted authorities to establish guidelines for safe occupancy loads. In the United Kingdom, the Sports Ground Safety Authority published the “Green Guide” which defines the safety limit for a standing crowd as 47 people per 10 square metres and 40 people per 10 square metres for a moving crowd. The Building Code of Australia (1996) recommends 2 people per square metre as the safe occupancy load for a standing area. Although these guidelines are beneficial in determining capacities of areas they must always be examined alongside the way and how crowds interact. For example, crowds do not fill areas evenly (Still, 2000) and at concerts it is evident that there is more congestion closest to the stage. Upton (2008) comments that controlling crowd density at a concert is very difficult and the natural laws of crowd dynamics produce lateral or dynamic surges that can become static loads in a crowd collapse. Therefore, event planners must identify high density areas and design these spaces to minimise risk the risk of crushing.

Crowd behaviour relates to how individuals interact with each other and how the crowd behaves as a mass. Still (2000) identified key behavioural characteristics of crowds. Crowds comprise many individuals, have no collective intelligence, form clusters, exploit short cuts, self-organise at high density and are influenced by geometry. Fruin (1993) commented

that a crowd is likened to a series of intermeshing cells, which have limited communication between them. This lack of communication may in certain circumstances lead to serious crowd incidents. For example, people at the rear of a crowd, where space is less restricted, press forward despite those at the front already being under pressure. Fruin (1993) also discusses the crowd behaviours of flight and craze. A flight response occurs where people experience a real or perceived threat and display cooperation rather than destructive behaviour. Craze behaviour is when people compete to obtain a desired objective such as being closest to the stage.

Crowd dynamics examines the relationship between the density, speed and movement (Still, quoted in Pelling, 2009) of a crowd. It explores crowd flow and how it is affected by individuals and the environment. Fruin (Still, 2015) modelled the effects of crowd density vs flow rate. He determined that flow rates increased up to between 2 and 3 people per square metre. After that the crowd is not free flowing and becomes increasingly unstable and dangerous. From this he calculated that an optimal maximum flow rate is 82 per metre per minute. This rate decreases when considering factors such as corners, staircases, crowd demographics and weather.

Still (2000) argues that higher flow rates can be achieved during activities such as ingress; however, they are only sustainable over a short period of time. A further factor disrupting flow rates occurs when people move in counter flows (Oberhagemann, 2012).

The study of crowd dynamics also enables the study of the interactions of individuals. This includes how individuals understand and interpret information, crowd demographics and the effects of management systems and geometry on the behaviour of crowds (Still 2000). Fruin (1984) argues that there are four interacting elements in a crowd situation: time, space, information and energy. These factors may be used to analyse crowd characteristics and therefore identify the risk inherent in crowd safety.

Risk analysis and crowd safety

Crowd incidents occur in a wide variety of venues and different circumstances (Fruin 1993). In 1989, 96 people were killed at the Hillsborough Stadium in Sheffield, United Kingdom. The interim and final reports (Taylor 1989, 1990) which detail this tragedy highlight the shortcomings in the planning process and made a series of recommendations in regard to how crowd safety could be improved at such events. Still (2013) examined crowd disasters between 1989 and 2013 and determined that in over half of the incidents, the design element was the fundamental causality of the issues, and if an appropriate risk analysis of the crowd and the space had been undertaken, there could have been a significant reduction in the resulting fatalities and serious injuries.

Risk analysis – a traditional approach

In Queensland, Australia, the Work Health and Safety Act 2011 (Qld) requires that the person with management or control of a workplace must ensure, as far as is reasonably practicable, that the workplace is without risk to the health and safety of any person. Failing to do so may result in the responsible person being held liable for an offence against this Act. Tourism and Events Queensland (2013) advise event organisers of their duty of care and to incorporate a risk management approach into their planning.

To manage risk, Workplace Health and Safety Queensland (2011) prescribes a risk management approach in the identification of hazards. This comprises the assessment of risks by the determination of the likelihood and the consequences of a particular risk and the implementation and review of control measures. Although this method is useful for promoting risk awareness in a workplace and for assessing some workplace activities, its effectiveness is limited.

Upton (2008) questions whether a quantitative approach is effective in predicting human behaviour. He argues that assessing risk in this way can lead to varying results as it is subjective, and individuals perceive risk differently. Still (2015) argues that this approach overestimates risk and that the information contained within the risk assessment is summarised and therefore difficult to effectively plan for the risks associated with crowds. A traditional risk assessment can also be manipulated by the assessor to validate a decision or to support a proposal.

Risk analysis – a crowd science approach

Event planning is only fully effective when an in-depth risk assessment of crowd safety is undertaken (Upton 2008). Although the safety of crowds can be complex, Still (2015) outlines tools and techniques that identify issues concerning the density, behaviour and dynamics of crowds. Still's DIM-ICE model considers three key influences on crowd behaviour; design, information and management and plots them against three phases of crowd movement; ingress, circulation and egress for both normal and emergency situations (Pelling, 2009). He recommends using a RAMP analysis to model the dynamics of crowds. This model examines the routes crowds use and how they access event areas; what and how areas and spaces are used; the movement of people, including arrival and departure profiles, flow rates and fill times; and the profile of the crowd including, demographics, known behaviours, type of event and the crowd's psychological profile. He advocates the use of colour-coded maps and plans by plotting the routes of crowds and mapping risk by shading plans to identify the density of crowds at different times during an event. He also suggests the use of a Decision Support analysis which is used to analyse one set of variables against another, for example, crowd congestion and event space.

Utilising such tools enables event planners to highlight areas and times of high risk, to plan for those risks accordingly and to control them through effective design, information systems and management strategies. Still (2015) argues that through crowd modelling, complex safety issues are simplified and that solutions can present themselves more simply.

Conclusion

This paper sets out the underlying theory of crowd science and its importance in understanding crowd safety issues. It discusses why risk analysis of mass gatherings is necessary and why traditional risk management strategies are limited in their effectiveness. Finally, it briefly outlines a new approach that when included in an event planning framework may significantly improve crowd safety.

REFERENCES

- Australia Building Codes Board. (1996). Building Code of Australia – Class 2 to Class 9 Buildings – Amendment 13.
- Department for Culture, Media and Sport. (2008). Guide to Safety at Sports Grounds – 5th Edition, viewed 8 June 2015. <http://www.safetyatsportsgrounds.org.uk/sites/default/files/publications/greenguide.pdf>
- Fruin, J. (1984). Crowd Dynamics and Auditorium Management. In International Association of Auditorium Managers (1984), Auditorium News. Viewed 2 June 2015. <http://www.gkstill.com/Support/crowd-flow/fruin/Fruin3.html>
- Fruin, J. (1993). The Causes and Prevention of Crowd Disasters. In Smith, R. A. & Dickie, J. F., Engineering for Crowd Safety, Amsterdam: Elsevier Science Publishers BV. Viewed 2 June 2015. <http://www.gkstill.com/Support/crowd-flow/fruin/Fruin2.html>
- Oberhagemann, D. (2012). Static and Dynamic Crowd Densities at Major Public Events: Technical Report vfdb TB 13-01. In Vereinigung zur Förderung des Deutschen Brandschutzes e. V. (vfdb), German Fire Protection Association.
- Pelling, K. (2009). Safety in Numbers, iSquared, Summer, pp. 23–26.
- Still, K. (2000). Crowd Dynamics. PhD Thesis presented to the University of Warwick, 2000, incorporating updates to 2013.
- Still, GK (2015). Fruin – Levels of Service, viewed 2 June 2015. <http://www.gkstill.com/Support/crowd-flow/fruin/Fruin1.html>
- Still, GK (2015). Introduction to Crowd Safety and Risk Analysis (APEL short course) 25–27 May 2015, Brisbane, Australia.
- Taylor, Lord Justice. (1989). The Hillsborough Stadium Disaster Inquiry Interim Report. London: HMSO.
- Taylor, Lord Justice. (1990). The Hillsborough Stadium Disaster Inquiry Final Report. London: HMSO.
- Tourism and Events Queensland. (2013). How to organise special events and festivals in Queensland, Seventh Edition, viewed 8 June 2015. <http://teq.queensland.com/en-GB/Industry-Resources/How-To-Guides/Organising-Events-and-Festivals>

- United Nations. (2014). World's population increasingly urban with more than half living in urban areas, viewed 10 June 2015. <http://www.un.org/en/development/desa/news/population/world-urbanizationprospects.html>.
- Upton, M. (2008). Safe Event Management. Paper delivered to the Theatre Managers Association Conference, Birmingham, 10 June 2008.
- Workplace Health and Safety Queensland (2011). How to manage work health and safety risks - Code of Practice 2011, viewed 8 June 2015. <https://www.business.qld.gov.au/business/running/workplace-healthsafety/laws/codes-practice>
- Legislation
Work Health and Safety Act 2011 (Qld)

Kevin Kennedy – crowd science in Canada

About Kevin

Kevin Kennedy is a Staff Sergeant with the Ottawa Police Service (OPS) and has over 36 years of policing experience, including 15 years with the Ontario Provincial Police (OPP). While working with the OPP he was a member of the East Region Emergency Response team from 1993–1998. One notable assignment included serving as unit leader for the Public Order Unit, which deployed to crowd situations in large demonstration-type environments. With the OPS, Kevin has worked within the Event Planning Section since 2009 and was promoted to his current position as the section supervisor in 2015. He currently leads a team of event planners that prepare police operational and deployment plans for large and medium scale events in Canada's National Capital. These events not only include festivals and celebrations but also large-scale demonstrations. Kevin has been the lead planner for several of the largest events held in the city that include the National Canada Day Celebrations, the National Remembrance Day Ceremonies, Bluesfest and the National Capital Marathon. He was also the lead planner for OPS's 2017 Event Planning Team for large-scale city events celebrating Canada's 150 Anniversary. Many of these events attracted tens of thousands of people congregated in spaces not designed for that magnitude of spectators.

In advance of Canada's 150th, Kevin recognised that there was a significant need for better awareness and education surrounding crowd safety. In 2015 he began researching crowd safety practices and subsequently discovered the theories and educational materials developed by Dr. Keith Still. He initiated arrangements for Dr. Still to conduct a three-day short course in Ottawa in 2016 for police, emergency and other city service personnel. Following the short course, he submitted two written papers to Dr. Still that were graded "With Distinction". Only a few Canadians have completed this requirement and he was the first to achieve this goal and to merit the honour of distinction.

In 2017 Kevin was instrumental in making the arrangements for Dr. Still to return to Ottawa to present a second short course. Prior to that session Kevin was provided the Train the Trainer Course – once again, the first Canadian to achieve this accreditation. As a result, he delivered some of the course material during the 2017 session and is planning on engaging in more training sessions in the future.

In 2019 Kevin began his Master of Science in the field of Crowd Safety and Risk Analysis with Manchester Metropolitan University. He has recently completed his second year of study and looks forward to submitting his Dissertation in the spring of 2022.

Kevin continues to advocate for the consideration and implementation of enhanced crowd safety measures for all events. While most of the previous training in Ottawa has been provided to police and service delivery agencies, his focus for future courses will be geared towards event organisers, believing that crowd safety is the responsibility of all engaged in an event, and is not restricted to the emergency personnel or support services.

Introduction

Historically speaking, crowds have always been a part of human existence. Whatever the reason, people have been drawn together with the expectation that in numbers, their personal safety would not be at risk. In fact, it has even been reported that people with like-minded purpose feel safer as the group size increases (Alnubulsi & Drury, 2014). However, a feeling of well-being is in no way an assurance of overall safety. There are many other factors that prove to be hazardous including, but not limited to, the physical characteristics of the venue, the nature and history of the event and the organisers' ability to address planning considerations. Each of these factors can impact the density of the crowd.

It has been suggested that density affects the psychology of both the individual and the crowd itself. Applying this understanding during the planning stages of an event may prevent loss of life, injury or property damage resulting from unsystematic attempts at crowd management (Berlonghi, 1995).

Definition: what is crowd science?

Crowd science moves beyond the simple definition of a crowd and studies the effects of the density and dynamics on the psychology of the individual and the group (Drury, 2015). Early studies focused on explanations for the transition from individualised thought to the "mob mentality". Crowd science moves a step further in studying how crowd density impacts crowd dynamics as a result of individual and crowd behaviour.

Key theories

The study of human behaviour in crowd situations is not simply an effort without purpose. "It's about understanding people's reactions and decisions when they're part of a group and learning to predict how they might move in any given situation" (Still, 2016).

Proxemics

In the 1950s and 1960s, Edward T Hall, a cultural anthropologist, promoted his term Proxemics to define his "study of how humans being communicate though their use of space" (Hall, 1963). He identified four zones surrounding each person (public, social, personal and intimate). Hall suggested a

person's behaviours are directly affected as a result of interspatial interactions and intrusions since we are all territorial by nature (Hall, 1989).

Crowd density as it relates to crowd dynamics

Crowd dynamics can be defined as the study of the how and where crowds form and move above the critical density of more than one person per square metre (Still, 2016). The dynamics will change as the density changes. Speed, flow rates and even sustainability are negatively affected by increased crowd density (Still, 2016).

With regards to legal issues (described later in this paper), it is important that one understands crowd dynamics as it pertains to the geography of a given site, in an attempt to reduce risks and promote overall safety.

Crowd behaviour

LeBon (1896) defined a crowd simply as a gathering of individual; whatever the chances that have brought them together. He suggested however that the psychology of a crowd can differ significantly from that of the individuals of which it is composed of. He stated that on some occasions the sentiments and views of the crowd can become the common mind set. LeBon proposed that the individual gives up his "conscious personality" adopting instead the group mentality. He identified it as an organised crowd, "a single being...subject to the law of the mentality unity of crowds" (Le Bon, 1896).

Social identity approach

The social identity approach recognises that each individual has his or her own personality; however, it also identifies that the individual has multiple social identities that dictate the way that one interacts with others in group settings. In this regard, identifying with a group in a crowded space setting provides a sense of security that would not be present if one did not identify as part of the whole (us vs. them). This could, in essence, impact how a person behaves in terms of trusting the group dynamic. It is possible that this could lead to conditioned behaviour, disinhibition and/or the occlusion of personal standards to remain as part of the group (Reicher, n.d.).

Legal issues

The Criminal Code of Canada is the primary legislation that deals with negligence when failing to properly plan or consider the ramifications of overcrowding for events.

Section 220 refers to criminal negligence resulting in death while Section 221 deals with those resulting in bodily harm. Section 219 defines criminal negligence as

- a. doing anything, or
- b. omitting to do anything
that shows wanton or reckless disregard for the lives or safety of other persons.

Section 219 applies to “everyone” and includes organisers, planners and responders. The burden of proof falls to the Crown Attorney in showing that there was a marked departure from the standard of a reasonable person, and in most cases, this is an overt act that is easily established. However, intention and deliberation are not solely necessary. In *R v. Sharp* (1984) indifference was found to be sufficient for establishing negligence. Therefore, it is incumbent on all planners and organisers to ensure that crowd safety is addressed and maintained in all stages.

Beyond the criminal aspect, civil courts, particularly in the United States, have heard a myriad of cases involving injuries that were sustained at crowded events. While there are no notable cases within Canada, the US cases focused on “duty of care”. If Canada had a similar disaster, failure to address potential issues would leave organisers and corporations at risk of civil litigation.

How it can be incorporated into event planning?

There are important elements that must be addressed to ensure the safety of a crowd. They include being aware of the social identity of the crowd (social rules/purpose), working with that group to safely achieve the goals of the gathering and to ensure open communication is maintained so that everyone is aware of the plan (Drury, 2015).

Planning and communications

It is important to understand that any crowd arriving at a venue will be influenced by the design and information provided upon approach and, from an organisers’ point of view, that these two elements can be controlled (Still, 2016).

Organisers can ensure that ingress and egress routes are of sufficient of a size and condition that they will safely accommodate the anticipated crowds. Furthermore, alterations to the design can be made in advance so as to minimise/eliminate any congestion that may occur.

After the organisers have established an overall plan, the information must be clearly packaged and communicated to the public in a manner that prevents any ambiguity. This includes media messaging in advance of the event and installing prominently displayed signage on site that directs crowd movement.

Not only does good communication provide people with information (facilities, locations, correct exits in an emergency), it can also enhance the relationship between organisers and attendees, in a virtuous relationship of trust (Drury, 2015).

Furthermore, a plan to address emergencies should be established in advance of the event. This plan must be communicated to the support staff so that they are informed on what is specifically expected of everyone. It has been proven that there are significant improvements in evacuation rates when trained people are in the crowds providing proper communications (Pelechano et al., 2005).

Tools

Members of the Ottawa Police Service (OPS) Event Planning Section have always developed detailed plans in advance of major events. Those plans always address crowd management issues, but they lack the necessary scientific foundation. In May 2016 OPS hosted Dr Keith Still, an expert and professor in crowd science. The tools acquired during the training identified that scientific support was lacking in the Canadian process.

The *DIM-ICE Model* designed by Dr Still commits planners to addressing the three key categories related to crowded space (design, information and management – DIM). These categories are separately addressed in the model during the various phases of an event (ingress, circulation and egress – ICE). This model can, and should, be developed in advance of an event for both normal and emergency situations (since both are dynamically different and, in many cases, differ significantly).

A *RAMP Analysis* (Routes, Area, Movement and Profile) is used to identify event characteristics that includes, among other elements, potential high-density areas, capacity restrictions and crowd types. This analysis highlights areas of concern so that the planners/organisers can properly address identified issues.

Another important tool is *Decision Support Analysis*. This tool is used to determine high- and low-risk situations for any number of comparable elements. In relation to crowds, it can be especially useful in highlighting high risk areas in terms of flow rates and crowd density during different periods of time. Using this tool will allow a planner to effectively adjust security and support to those areas for a given period of time.

Conclusion

Safety and security are paramount during any event. To achieve this, appropriate planning and organization is essential to ensure any potential risks are minimised and manageable. Since organisers are generally focused on attracting more patrons, crowd management must be considered at every stage of the planning process. Properly forecasting potential crowd issues through a comprehensive pre-event analysis will ensure that the event runs smoothly, the patrons enjoy a positive experience and the organiser achieves the successes intended.

REFERENCES

- Agnes, O. M. (2012). Proxemics: The Study of Space. *The Indian Review of World Literature in English*. 8(1). 1–7. Available at <http://worldlitolonline.net/proxemics-the-o.pdf> [worldlitolonline.net] [Accessed 9 Aug. 2016]
- Alnubulsi, H. & Drury, J. (2014). Social Identification Moderates the Effect of Crowd and Boundaries. Man's Image in Medicine and Anthropology, Density on Safety at the Hajj. *Proceedings of the National Academy of Sciences of the United States of America*. 111(25). 9091–9096. Available at <http://www.pnas.org/content/111/25/9091.long> [pnas.org] (09 August 2016)
- Drury, J. (2015). Bringing Crowd Psychology into Event Safety Management. Available at <http://www.festivalinsights.com/2015/07/bringing-crowd-psychology-event-safety-management> [festivalinsights.com] [Accessed 9 August 2016].
- Government of Canada, Statistics Canada 2016, Civil Court Survey, General Civil Cases by level of court and type of action. Available from <http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=2590013> [statcan.gc.ca] [Accessed 9 August 2016].
- Hall Edward, T. (1963). Proxemics: The Study of Man's Spatial Relations. Available from http://www.uni-kiel.de/psychologie/ispp/doc_upload/Reicher_crowd%20dynamics.pdf [uni-kiel.de] [Accessed 9 August 2016]. New York: International University Press.
- Hall Edward, T. (1989) Beyond the Culture. New York: Anchor Books.
- Le Bon, G. (1896). The Crowd – A Study of the Popular Mind. Available at <https://socserv2.socsci.mcmaster.ca/~econ/ugcm/3ll3/lebon/Crowds.pdf> [socserv2.socsci.mcmaster.ca] [Accessed 9 August 2016].
- Martin's Annual Criminal Code -2016 Police Edition, 2010, Thomas Reuters, Aroura.
- Pelechano, N., O'Brien, K., Silverman, B., & Badler, N. (2005). Crowd Simulation Incorporating Agent Psychological Models, Roles and Communication, University of Pennsylvania Scholarly Commons. Available at: <http://repository.upenn.edu/cgi/viewcontent.cgi?article=1033&context=hms> [repository.upenn.edu] [Accessed 9 Aug. 2016].
- R. v. Sharp, (1984) 3 O.A.C. 26 (CA) - Canadian Case Law
- Reicher, Stephen (n.d.) The Psychology of Crowd Dynamics, School of Psychology, University of St Andrews. Available at: <https://pdfs.semanticscholar.org/2ed1/dacbd7177d6c1709dda3a8254e7e58a6d1af.pdf> [pdfs.semanticscholar.org]
- Still, G. K. (2013). Introduction to Crowd Science. Boca Raton: CRC Press.
- Still, G. K. (Dr.) (2016). Book – Introduction to Crowd Science XE “Introduction to Crowd Science”. Available at: <http://www.gkstill.com/Support/Book.html> [gkstill.com] [Accessed 15 July 2016].
- Still, G. K. (Dr.) (2016). Crowd Modelling: Crowd Safety in the Complex and Built Environment. Available from: <http://www.gkstill.com/Support/Links/Documents/dim:ice.pdf> [gkstill.com] [Accessed 15 July 2016].
- Still, G. K. (Dr.) (2016). DIM-ICE Risk Analysis. Available from: <http://www.gkstill.com/Support/WhyModel/dimice.html> [gkstill.com] [Accessed 15 July 2016].
- Still, G. K. (Dr.) (2016). PhD Chapter 1- Introduction. Available from: <http://www.gkstill.com/CV/PhD/Chapter1.html#previous-photo> [gkstill.com] [Accessed 15 July 2016].
- Still, G K (Dr.) (2016). PhD Chapter 3 – Crowd Dynamics. Available from: <http://www.gkstill.com/CV/PhD/Chapter3.html> [gkstill.com] [Accessed 15 July 2016].

Ryoki Murayama – crowd science and simulation

About Ryoki

Ryoki received a Master of Engineering degree from the University of Electro-Communications, Japan in 2018. From 2017–2018, he was a research assistant in the Artificial Intelligence Research Centre at the National Institute of Advanced Industrial Science and Technology, Japan. In 2016, he spent a year as a research student in the U.K. awarded a Japanese government-sponsored scholarship. He has been working at the Tokyo Metropolitan Government. His research interest is pedestrian flow prediction in large scale events or disasters.

Crowd science

From relatively simple structures on a minute scale, like cells and cellular tissue, to large animals like insects, fish, birds and mammals, the formation of herds is a universal concept.

Despite the biological characteristics of each being very different, there are similarities in the behaviour patterns of each animal. Even though the leader of a herd may have no way of sharing information with others, they can cooperate as a whole group and take actions.

Self-driven particle

In order to understand this phenomenon, the "Self-driven particle" theory was developed, and theoretical studies have been conducted from the standpoint of statistical physics. Vicsek (2006) shows that group movement is born from simple self-driven particles – a pioneering statement in a developing field.

There are patterns derived from this research which can be seen in the activity displayed by human pedestrians. In daily life in cities, large numbers of pedestrians move, each with their own destination and intention in mind whilst being aware of those around them. This is the concept of self-organization.

Another example is the flow of pedestrians through a single passage. In this case, pedestrians do not take up random positions in the passage width; they have a tendency to follow other pedestrians who move in the same direction.

As a result, lanes are formed by the pedestrians walking in certain directions in the passage. This lane formation is more than a culturally derived custom and appears even when there is no written instruction in regard to the movement.

Pedestrian movement

Observation-based studies in pedestrian movement in traffic engineering and social psychology have been conducted since the 1950s. In addition to this, there was an attempt to create a hydrodynamic model of pedestrian movement in the 1970s (Henderson, 1971).

However, it was difficult holistically to cover this area and to include the results of pedestrian responses to bump or not to bump into each other and slowing down/speeding up in the passageway owing to the early modelling problems.

Thus, a new model appeared which considered each pedestrian as an individual agent. This model was able to describe the movement that occurs between agents – allowing pedestrian studies using simulation to develop. It is often thought that the patterns seen in crowd movement are the result of each pedestrian's complicated action principle.

However, in fact we can reproduce a person's actions through applying relatively simple reactionary action rules. Those pioneered by the social force model of Helbing and Molnar (1995).

The mechanical pedestrian model, which originated with the social force model, has been successful in recreating various features of self-organizing phenomenon seen in pedestrian movement. In all of these models, the effects of traffic rules, laws and their cultural effect on pedestrian movement have been restricted, proving that these phenomena are not the result of external factors.

Crowd dynamics

The dimensions of the human body have important implications for pedestrian monitoring. Such dimensions are used when planning the passage width and flow patterns for events and for emergency evacuation planning.

Fruin (1971) took the basic human elliptical model as having a shoulder breadth of 60cm and thickness of 45cm. He went on to consider how this shape impacts on crowd density and levels of service.

The architectural Institute of Japan (1981) investigated crowd density in a resting state at densities of 1 person per metre squared to 13 people per metre squared. For example, a density of 5 people per meter squared can be likened to a small full elevator. Each person does not encounter those in front/behind. A person can read a magazine, but they cannot pick it up easily if dropped. In addition, in the space design of evacuation behaviour, the shoulder breadth and projected area of humans become a problem. Okada et al. (1977) investigated the area taken up by people of various measurements.

Crowd accident

Of course, crowd flow is simply the accumulation of the actions of many pedestrians. However, there are cases in which crowd movement goes beyond the intentions of each individual and leads to a rushing movement. Crowd accidents are likely to occur at the times like these. In crowd accidents, people at the back bump or collide with people in front of them and in many cases to the side, thus causing multiple collisions in the space.

Another type of crowd accident is a crowd avalanche, where the careful balance of the high-density crowd breaks down and people collapse in many directions, according to the accident investigation report from the Akashi

Crowd Crush Disaster that occurred in Japan in 2001. The stampede developed as those in the back fell on those in front. Even with a relatively low density of 3 to 5 people per metre squared. In contrast, crowd avalanches are said to only occur when the density is more than 10 people per metre squared.

Crowd density and human pressure

According to experiments conducted into the relationship between crowd density and pressure where a wall is used to measure the pressure. Pressure starts from a density of around 10 people per metre squared. In a situation with a density of 12 to 13 people, there are around 3.5–3.6 people for every 1 m of wall. The pressure on the wall is over 200–450kg/m (Architectural Institute Walking Speed).

Henderson work (1971) can be seen as a classic example of the study of walking speed. This study examined the speed distribution in pedestrians crossing a Sydney crosswalk. There are many different conditions that define walking speed. According to Okada (1977), they can be organised into five categories.

- a. Physical conditions: sex, age, height, weight, health condition, etc.
- b. Collective conditions: number of people in the group, type, density, presence of oncoming people, presence of people crossing, etc.
- c. Dress conditions: the shape and importance of clothing, footwear, handheld items, etc.
- d. Psychological conditions: purpose, emotions, degree of familiarity with location, etc.
- e. Environmental conditions: season, weather, temperature, wind direction, time of day, quality of road and shape, gradient, brightness, visibility, etc.

There is a recent research from the UK in which the differences in average speed of pedestrians on a city sidewalk during the day were measured according to physical conditions, collective conditions and dress conditions (Willis, 2004).

Crowd behaviour

The behaviour of individual pedestrians is affected by a series of pedestrian space characteristics such as (1) macro conditions including indoor/outdoor, lighting, ventilation, noise, etc.; (2) size and shape of the space; and (3) floor characteristics such as flat paths, stairs and escalators, etc. A crowd flow is formed when pedestrians gather despite being affected by the above features. Crowd flow is separated into these six types, depending on its shape.

1. One-way flow: flow of pedestrians in one direction only
2. Counter flow: flows of people in two directions facing each other
3. Laminar flow: opposite directions, a situation in which a crowd flows in more

4. than three directions. Laminar flows are usually naturally created at crossings with large numbers of people, called lane formation
5. Cross flow: a situation in which two crowd flows in different directions pass through each other, for example, at the scramble crossing
6. Stream crossing: a situation in which crowds flowing in many directions pass; for example, movement of people through a station or customers in a store
7. Overflow: the movement of the faster pedestrian to overtake people walking at a slower pace

Crowd density and walking speed

The fluidity coefficient refers to the number of people that pass through 1-metre-wide passage per second. It is the product of speed and density.

Apart from stairs and significant bottlenecks, the average crowd is estimated as 1.5 people per second per meter. Around 1.2 people when climbing stairs and around 1.0 people in a customer facility (Architectural Institute of Japan, 1980, p. 56).

The linear equation of density – the velocity model is often referred to as the “Fruin type”. However, in this case, the graph becomes a quadratic convex, and a density of 4 results in the flow equation being zero.

Normal times and stress times

Pedestrian behaviour also changes significantly between normal times and during times of stress. Stress-related behaviour can occur when life-threatening events such as fires occur in crowded environments, but can also occur when, for example, people want to get good seats at a concert, or even when there is no clear reason.

Recently, large-scale events in cities, which are becoming more convenient places to live, are on the rise, and stress-related accidents are also increasing.

However, social psychologist such as Hirose (2004) has noted panic as a possible cause of accidents where no other cause can be identified. It has been identified in inspections that this can be the cause of accidents. The characteristics of pedestrian behaviour during panicked times are (1) nervous and quick behaviour; (2) tunnel vision, for example, not finding other exits; (3) blind following of the action of others; (4) pushing/jostling; (5) non-cooperative behaviour when passing through bottlenecks; (7) occurrence of jams, arching and clogging.

Crowd risk analysis

When one considers or measures advanced reasons for crowd accident or risk one can use a simulation of human behaviour and space model which makes it possible to find areas where density issues are likely to occur and how they can

be moulded to manage crowd flow. In Japan, the Akashi Crowd Crush Disaster of 2001 resulted in 11 deaths (9 people under 10 years old) and 247 were injured. As a result of this disaster, rules regarding the responsibility of event managers were put in place and the importance of pre-planning was identified.

Event tree analysis

As a method of quantifying this large-scale, complicated system's risk, there is the Event Tree Analysis. It was originally used by the UKAEA (United Kingdom Atomic Energy Authority) to evaluate the areas in which nuclear reactors were to be constructed.

The International Electrotechnical Commission has standardised the ETA risk assessment for use internationally, and an IEC62502 was issued in 2010, leading it to be used in a wide variety of fields today.

Risk matrix

One other main technique is the Risk Matrix. By making clear the frequency of occurrence of the harm and the potential damages on a chart. It is possible to visualise and rank the risk. In Still (2009), the DIM-ICE risk model was considered as a more effective model for crowd risk. In this model, it is possible to evaluate risk during normal times and emergency situations.

Conclusion

In this paper, the behaviour and actions of crowds, and the key risk theories were discussed. Crowd accidents are a major social problem. Evacuation behaviour has been studied for many years in the architectural engineering sector. In addition, there are also many sociopsychological studies about human behaviour analysis.

Despite there being similar challenges in both of these fields, there have been few studies incorporating both fields. Crowd science is a field that crosses a large number of research fields and thus it is interdisciplinary. The basic research has been mainly completed, and now work must be done to create a more sophisticated theoretical base and compile more event and evacuation data to prevent crowd accidents and contribute to a safer society.

REFERENCES

- Akashi City Summer Festival Accident Investigation Committee. (2002) Accident Investigation Report on the Firework Festival at the 32nd Akashi City Summer Festival. (in Japanese)
- Architectural Institute of Japan. Architectural Design Data Corpus 3, Environment 1". Maruzen, 1981.

- Fruin, J.J. (1971) Pedestrian Planning and Design. Metropolitan Association of Urban Designers and Environmental Planners, Inc. New York.
- Grimston, M. C. & Nuttall, W. J. (2013) The Siting of UK Nuclear Power Installations, CWPE 1344 & EPRG 1321. <http://www.econ.cam.ac.uk/research/repec/cam/pdf/cwpe1344.pdf> [Accessed 29 Aug. 2016].
- Helbing, D., & Molnár, P. (1995) Social Force Model for Pedestrian Dynamics. *Physical Review E Phys. Rev. E*, 51(5), 4282–4286. doi:10.1103/physreve..51.4282.
- Henderson, L. F. (1971) The Statistics of Crowd Fluids. *Nature*. 229(5284). 381–383.
- Hirose, H. (2004) Whether Fail to Escape Why do people – Psychology of Disaster, Shueisha, Japan. (in Japanese)
- IEC 62502. (2010) Analysis Techniques for Dependability—Event Tree Analysis (ETA)
- Okada, K., Yoshida, K., Kashiwara, S., Tsuji, M. (1977) Human Engineering of Architecture and City-Mechanism of Space and Behavior. Kajima Institute Publishing, Japan. (in Japanese)
- Still, K. (2009) Safety in Numbers, ISquared, Summer, pp. 23–26. http://www.gkstill.com/Support/Links/Documents/2009_still.pdf [Accessed 29 Aug. 2016].
- Vicsek, T., Czirók, A., Ben-Jacob, E., Cohen, I., & Shochet, O. (1995) Novel Type of Phase Transition in a System of Self-Driven Particles. *Physical Review Letters*. 75(6). 1226–1229. doi:10.1103/physrevlett.75.1226.
- Willis, A., Gjersoe, N., Havard, C., Kerridge, J., & Kukla, R. (2004). Human movement Behaviour in Urban Spaces: Implications for the Design and Modelling of Effective Pedestrian Environments. *Environment and Planning B: Planning and Design*. 31(6). 805–828.

CROWD SCIENCE CASE STUDIES

Knowledge without application is like a book that is never read.
Christopher Crawford

In this section, we show examples of the case studies from international practitioners, using the modelling tools for major events. We have reproduced the work in full colour as the grey-scale images (for the print copy) lost too much information.

When presenting your work, we recommend the following procedure.

1. Select a relevant map, plan or diagram
2. Import to your word processor, presentation tool or spreadsheet
3. Select image and then reduce the saturation to zero (this makes it grey scale)
4. Then add your Red/Orange/Green lines and areas

That will make your graphics easier to distinguish from the background.

Kristin Finn – Rugby World Cup, Fan Zone

An evaluation of the Rugby 2015 World Cup Fan Zone site, Exeter

Kristin Finn is a Lecturer in Event Management for the Department of Tourism and Hospitality at Plymouth University, and her main teaching roles are in crowd management, research and consultancy, and operational planning for events. Specifically, her research interests lie in matters relating to crowd behaviour, managing safety and the relationship between crowds and audience experience at events.

Prior to joining Higher Education, she worked in consultancy for almost ten years, most notably developing project evaluations, monitoring frameworks and organisational strategies for local government as well as visitor and audience behaviour studies for tourism, cultural and events organisations in the public and private sectors. This range of experience informs her teaching contribution and areas of professional interest.

Introduction

As a host city for the 2015 Rugby World Cup in September, Exeter City Council announced the provision of a free 5000 capacity fan zone site located in Northernhay Gardens. This was made available for the thirteen match days over the six weeks of the event in the heart of the city centre for fans and all those who were unable to secure tickets (Heart of Devon 2015). Northernhay Gardens is a popular location for outdoor events in the city owing to its central location and proximity to a variety of transport links. The Gardens are utilised annually for the Exeter Festival of Southwest Food and Drink (Exeter Food and Drink Festival 2015) as well as Big Screen in the Park (Exeter Phoenix 2013) amongst other events. The site accommodates up to 5000 people, with facilities which include a big screen, food and beverage outlets, merchandise stalls, toilets and information facilities (Hatfield 2015). However, the site is not without its challenges. This paper analyses the suitability of the Fan Zone site, exploring potential issues associated with crowd flow, congestion and site design. This is then utilised to map risks and present recommendations for an appropriate crowd management strategy for the event.

Analysis of Rugby Fan Zone site, Exeter

Tum et al (2006) suggest that the three fundamental on-site issues to be addressed through layout planning are to optimise movement, reduce congestion and maximise the use of space in an event site. Underpinning this concept is the importance of site planning in ensuring crowd safety and positive customer experiences at events. Rutherford-Silvers (2008, p. 247) argued that the design of the event setting must strive to encourage desired behaviour in a range of ways linked to the functional environment of the event.

Building on this, Still (2014) identified the need to evaluate several aspects in relation to crowd dynamics. First is RAMP analysis, which looks at

evaluating event routes, areas, movement and profiles. Second is modelling crowd risk according to ingress, circulation and egress as well as design, information and management (DIM-ICE). Third is decision-support analysis. Fourth is the need to develop risk maps for the event site. This analysis has been conducted for the Fan Zone site.

RAMP analysis¹⁶ – routes (directions)

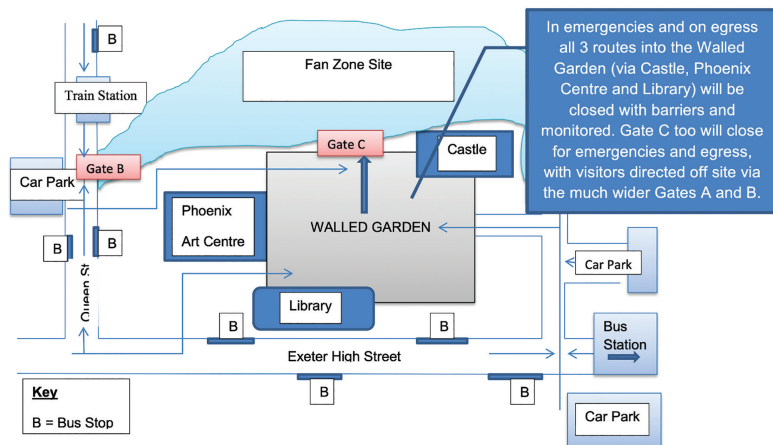
Crowds will ingress and egress the Northernhay Gardens site from three main access points (Figure 56): the High Street gate (A), the train station gate (B) and three smaller entrances into the walled park from the Exeter Phoenix Arts Centre, the library, and the castle (adjacent to Northernhay Gardens). These converge into one gated entrance (C) taking the attendees to the main Fan Zone site. Two main roads wrap the entrances to the site, Queen Street and the High Street, of which there are three multi-storey car parks, a train station, a bus station and 7 bus stops. Each of these transport points is within a two-minute walk of one of the gates to the venue.

Areas

The area around each ingress and egress gate will be manned by stewards to monitor visitor numbers and will include an information point. For this reason, it is expected that these areas will experience casual, walking and ambulatory crowds (Berlonghi 1995). The challenge for organisers will be to facilitate a steady flow through these nodes. The large screen integral to the fan zone is positioned at the west end of the park, close to Gate B (Queen Street Entrance) with restricted staff-only access directly behind it. A first-aid point is also positioned by Gate B. In front of the screen and stage in the centre of the fan zone is expected to be a free-standing and seating area (GA) with toilet facilities to the north boundary of the site. Crowds in this area may be seated, standing, migrating or queuing and at this point the crowd will most likely become dense. The area nearest to Gate A (High Street entrance) will house the food and beverage concessions and further toilet facilities. It is expected that queues may form in this area, with crowds becoming densest at peak arrival times and between scheduled entertainment slots or matches. A detailed map of the site areas is shown in Figure 56.

¹⁶ This is a case study event only - access to specific site dimensions was unavailable to inform maps.

Routes on to and off site, plus transport hubs



Site Areas

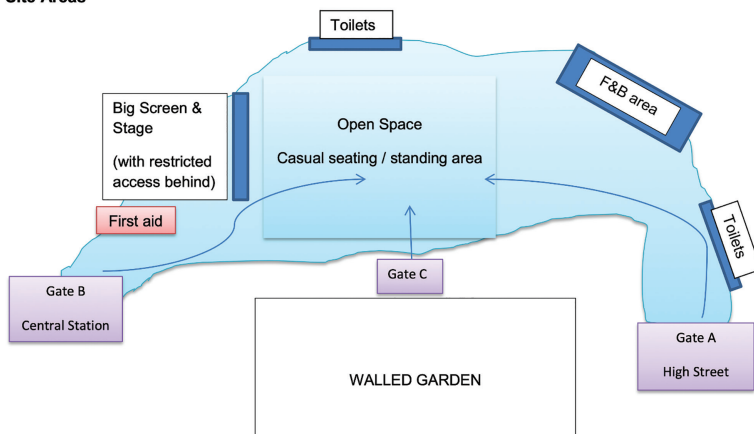


Figure 56 Site, routes, hubs, and areas

Movement

Flow rates will be wholly dependent on the timing of the matches to be shown on the big screen and the entertainment available in the fan zone well as the site opening time of the site each day. Unfortunately, without full access to this information, flow rates can only be crudely estimated. However, a fan zone schedule for Tuesday 29th September 2015 (Heart of Devon 2015) was available and has been used to estimate flow rates. Depending on match times and entertainment available, flow rates are likely to also be influenced by public transport arrivals from the arterial routes (trains and buses/park and rides). The stage programme and public transport¹⁷ options for the day to help estimate flow rates (Figure 64). The fans will be pulsed

¹⁷ National Rail Enquiries 2015; Stagecoach Exeter 2015.

from the arrival sites towards the fan zone in time with schedule enabling some intelligence to be gained from bus and train timetables.

Fan zone stage programme – September 29th (Heart of Devon 2015)

11:00–13:00 – Schools music line up

16.00–16.10 – Fanzone Advantage new artists and bands

16:15–16:45 – Live Screening Rugby World Cup 2015

16.45–18.45 – Tonga v Namibia live screening from Sandy Park, Exeter

18.45–19.00 – Phoenix Film

*19.00–20.30 – Zuri Aura -5-piece Afrobeat/ Reggae/Dub band Zuri Aura
Train Arrivals Bus Arrivals*

*18, 19, 28, 37, 51 & 52 16 routes arriving every 10–15 minutes
mins past every hour*

As there is little entertainment taking place ahead of the match on the specified day, visitor flow to the site until lunchtime is expected to be relatively low, perhaps centred mostly on walk-ins. A slow-to-steady flow at the gates and around the site is likely from opening until approximately two hours before the match starts and whilst the match is being played, when it is anticipated that most visitors will have arrived.

Increased flow is likely to be experienced at the gated entrances in the two hours leading up to match airtime owing to public transport arrivals, with 6 trains arriving per hour and 16 bus routes arriving in the centre every 10–15 minutes per route. At these times the standing and seating area will begin to fill. However, arrivals by car and walking will provide the largest proportion of visitors, with walkers being local to the area and high car use identified as a key characteristic of Exeter's day trip market (Heart of Devon, 2006). Car users (including park and ride visitors) and walkers are expected to greatly increase in numbers during this two-hour timeframe with peak flow likely to occur within one to one-and-a-half hours of the match start. At this point it is expected that the site will be near to or full, reaching its 5,000 people capacity. It is likely that egress bottlenecks will also be experienced at the match end and following the evening band entertainment post-match.

Profile

Based on previous events held in this venue including the Big Screen in the Park (Exeter Phoenix, 2013) and based on the common typologies of sports fans (Bladen et al., 2012), the event is likely to attract a range of ages and group types, including families, friends and sports fans of varying degrees of commitment. Arguably, these crowds will mostly be revellers and expressive, enjoying the atmosphere (Berlonghi, 1995; Rutherford-Silvers, 2008) or as Canetti (1973) would define them, a “feast” crowd.

It is important to also understand the fan dynamic and the sports event subculture which can indicate potential for rivalry between supporters and excessive consumption of alcohol that can exacerbate certain situations (Dun, 2014; Green & Chalip, 1998; Henderson, n.d.). With the large range

of audience types likely to be in attendance, a strong steward and security presence as well as emergency strategies involving the police and other emergency services are required. However, it can also be noted that the preponderance of rugby fans will provide a less exuberant and violent type of spectator than that of a football crowd.

DIM-ICE evaluation

The design, information and management of the Exeter Rugby World Cup Fan Zone event has been analysed according to ingress, circulation and egress scenarios for both normal and emergency periods. As can be seen in Tables 23 and 24, the event site is suitable for its size and could be considered as relatively low risk overall, with appropriate procedures in place generally for ingress, circulation and egress in both normal and emergency scenarios. The main areas for concern and high risk are linked to the restricted width of Gate C and the subsequent need to close and monitor this gate for egress. Moreover, the Walled Garden beyond Gate C is dimly lit at night which could present a risk to visitors. This demonstrates the need for its closure (from all access points) as well as the Gate C exit directly attached to it.

Congestion/Risk maps for the site

According to Helbing and Mukerji (2012), crowd surges and safety scenarios are not always avoidable as crowds are often unaware of the domino-effect dangers involved in dense crowd situations. Following the RAMP and DIM-ICE analysis conducted for the Rugby World Cup Fan Zone site, congestion risk maps have been produced below to identify low- (green), medium- (amber) and high-risk (red) congestion areas at different points in time within the event. Figure 57 considers the changing crowd scenarios linked to the event opening time (11 am), peak ingress (2–3.30 pm), match/entertainment time (4–8 pm) and event closure/egress (8.30 pm).

Decision support matrix/analysis

From the decision-support analysis conducted, high risks of crowd density (Table 25) are centred around the peak ingress and egress times on the gates and during match showing and entertainment for on-site areas. Lines of communication are expected to be good generally (Table 26) although ensuring clear separation of tasks is crucial, and audience clashes and acceptance issues may be observed owing to rivalries and intoxication. Direct liaison with the police will require swift action by organisers as well as issues raised by staff team members.

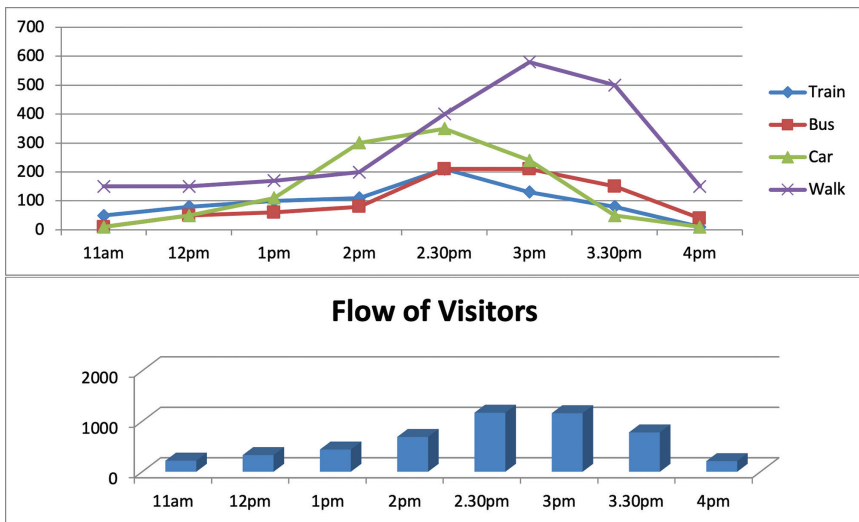


Figure 57 Anticipated arrival flow (modal split) and likely visitor flow

Conclusion and recommendations

The analysis presented within this paper sets out the required crowd management and control planning that should be implemented in both a normal and emergency crowd situation for the 2015 Rugby World Cup Fan Zone event in Exeter using the tools identified. The site of Northernhay Gardens is event-appropriate owing to its central location with close links to key transport hubs and several routes onto site to alleviate the pressure on a single gate. In the case of an emergency, lines of communication, roles and tasks must remain clear amongst all event stakeholders and in the case of an emergency egress, organisers and staff should act closely and monitor Gate C as well as the three ingress points to the Walled Garden, redirecting visitors to leave the site through either Gate A or B instead.

Peak flow is expected within two hours leading up to the start of the match on the gates as well as upon egress. Peak flow is also expected in the main event space in front of the screen and stage and by F&B and toilet facilities during the match and also during post-match entertainment.

This event will attract a broad range of visitors, and whilst most will be peaceful, it is anticipated that clashes could occur among fans or those who are intoxicated presenting issues in terms of managing audience communication. At egress in particular, a greater police presence may be required to safely monitor, manage and escort fans from the premises.

Table 48 DIM-ICE Analysis. Normal

NORMAL	Ingress	Circulation	Egress
Design	Free entry non-ticketed event whereby gate staff count visitors onto site. Wristband entry system to help ensure capacity is not breached. Visitor numbers to be monitored upon entry. Multiple (3) ingress / egress routes. Signed transitory routes to view area in central open space	Flows expected to build up to start of match. Site map leaflets provided on entry. Signage position in sight line of entry and at key places to move visitors through the main event space. Barrier lane entry to be deployed primarily to accommodate the peak flow time 2 hours prior to match start Stewards to monitor bottlenecks at entry and near F&B and toilet facilities. F&B and toilet facilities likely to become congestion directly before match start, during half time, and at match end.	Bottlenecks likely at end of match for the three key egress points (Gates A, B and C). Sufficient width to accommodate flow at Gates A and B. Gate C is narrow so closed for egress. Flow redirected by stewards to either Gate A or B.
Information	Signs to open viewing area and stage. Information booths located next to entry gates. Pre-event publicity to provide key transport information, directions and expected crowds with a capacity limit of 5000 maximum	Signage aimed at directing people around the site. Stewards deployed to monitor busy areas on site	Signage routes for egress off-site through Gates A and B, and away from the venue to key transport hubs clearly marked. Staff / stewards clearly identifiable to move visitors off-site. Site closing information shared on the Big Screen
Management	Stewards/security to count numbers entering site and distribute wristbands Stewards present in information booths. Stewards present in viewing area. Monitoring of arrival flows to site in city centre by organisers and police	Good communication systems in place Two-way radio communications between gate staff organisers, plus organiser contact with emergency services (when required). Clear routes and directions for visitors to and around the site Strategy for crowd congestion at key times in key locations in place	Good CCTV around the City Centre to monitor egress flow Communication between organisers and police Fully briefed staff and volunteers to aid smooth egress.

Table 49 DIM-ICE Analysis – Emergency

EMERGENCY	Ingress	Circulation	Egress
Design	Pinch point at Gate C from Walled Garden entrance to site at peak times potentially. All other gates easily accessible with sufficient space for visitor numbers expected. Ample off-street space to accommodate barrier queues on entry at all 3 gates.	Hazards and restricted areas clearly marked (particularly restricted area behind the Big Screen and stage). Sufficient venue space for capacity of 5000. Stewards deployed to manage congested areas at peak times.	Bottlenecks and congestion likely if visitors try to exit through Gate C. therefore gate to be closed for egress at end of event with staff deployed to gate to redirect flow in opposite directions for Gates A or B. Walled Garden dimly lit at night, so all entrances closed off and monitored to avoid visitor injury.
Information	Good signage to venue and good communication channels in place.	Big screen used for messages to crowd and PA system in place.	Staff to relay information updates via Big Screen and tannoy. Police presence outside to help manage emergency egress off-site in areas around High St. and Queen St.
Management	Staffing levels are good due to a strong volunteer base as well as core event staff. Careful monitoring of entrance gates and city centre approaches. Strong communication with police.	Careful monitoring of crowd congestion. Clear roles defined in a circulation-based emergency for staff working in specific event zones. Event stop procedure in place if required.	Good CCTV around city centre to pinpoint emergency scenarios. Clear. Stewards to manage safe and swift egress on-site until venue is cleared.

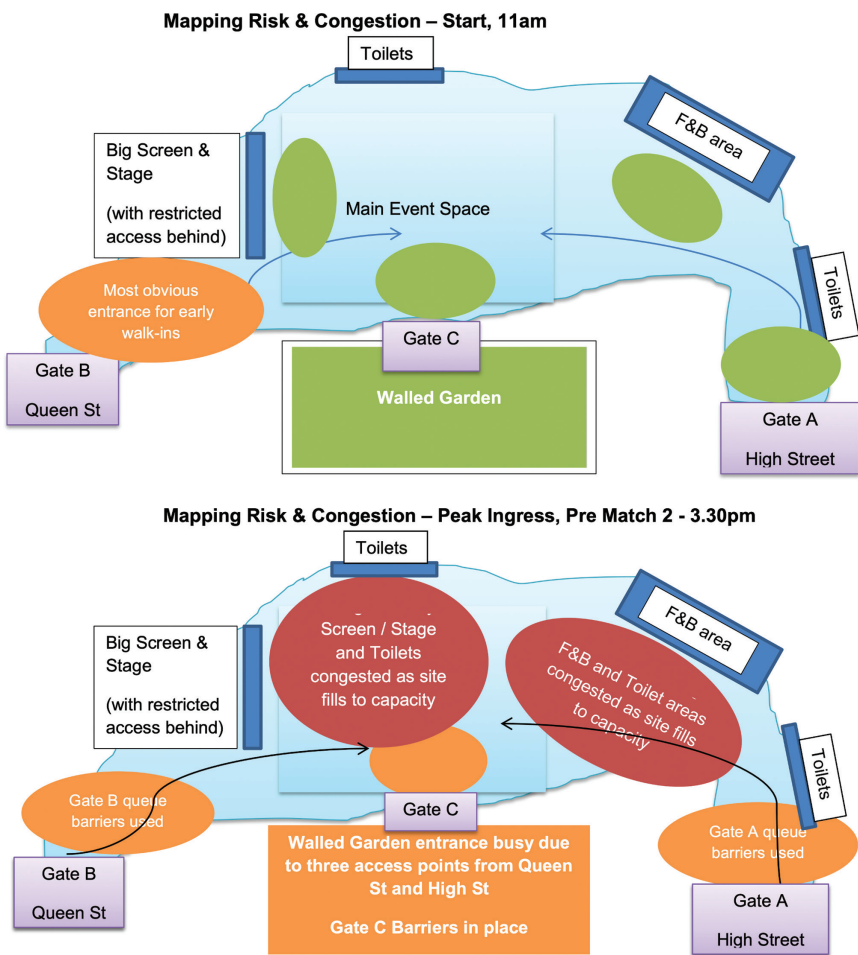


Figure 58 Mapping risk and congestion (start time 11 am and pre-match 2–3:30 pm)

REFERENCES

- Berlonghi, A.E. (1995). Understanding and planning for different spectator crowds. *Safety Science*. 18. 239–247.
- Bladen, C., Kennell, J., Abson, E. & Wilde, N. (2012). *Events Management: An Introduction*. Oxon: Routledge.
- Canetti, E. (1973). *Crowds and Power*. London: Penguin Books. Translated by Carol Stewart.
- Dun, S. (2014). No beer, no way! Football fan identity enactment won't mix with Muslim beliefs in Qatar 2022 World Cup. *Journal of Policy Research in Tourism, Leisure and Events*. 6(2). 186–199.

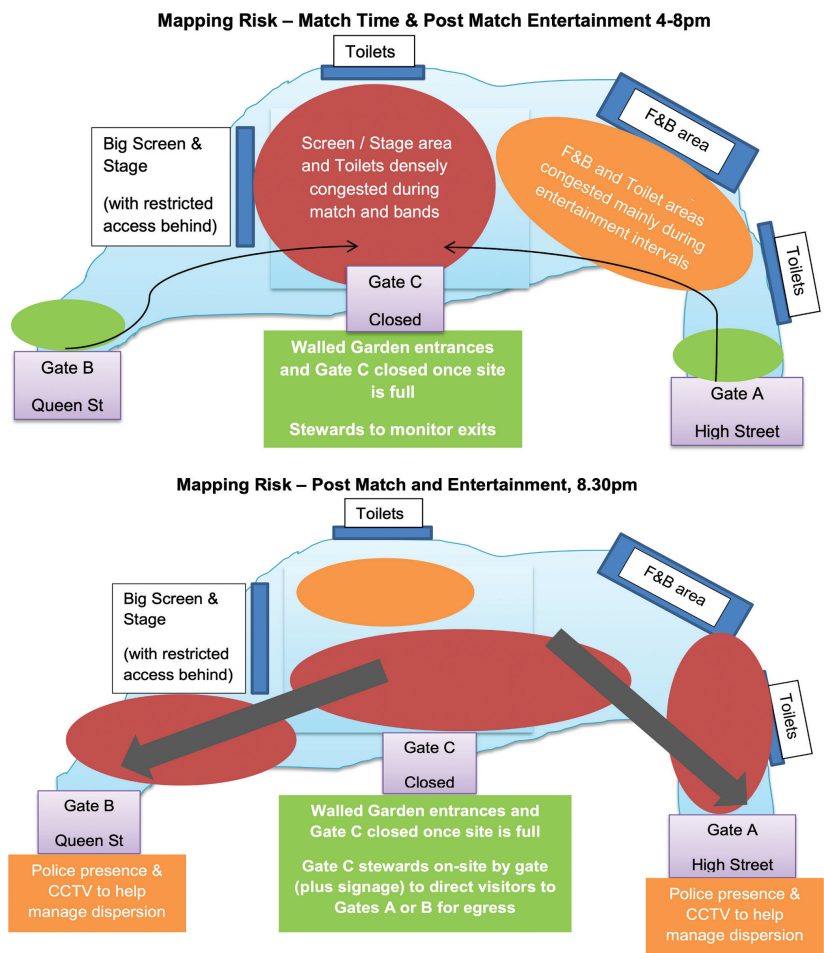


Figure 59 Mapping risk and congestion (4–8 pm and post-match 8:30 pm)

Table 50 Crowd Density / Movement. Risk Profile By Area

	11 am	12 pm	1 pm	2 pm	3 pm	4 pm	5–8 pm	8.30 pm
Gate A	Med	Med	Med	High	High	Med	Low	High
Gate B	Low	Low	Med	High	High	Med	Low	High
Gate C	Low	Low	Med	Med	High	Low	Low	Low
Pathways	Low	Low	Med	Med	High	Med	Med	High
Main stage & screen area	Low	Low	Med	Med	High	High	High	Med
Toilets	Low	Low	Low	Med	Med	High	High	Med
F&B area	Low	Low	Med	Med	High	High	High	Low

Table 51 Communication Decision-Support Matrix

	Organiser		Police	First Aid	Staff	Security	Audience
Organiser	Radio sets Clear communications, clear emergency communications plan	Liaison in control room	Clear briefing & incident plan, radios	Clear tasks & line of communications, radios	Clear tasks & line of communications, radios	Big Screen and gate info, loudspeakers, Clear online info	
Police	Clear terminology, radios, CCTV	Clear tasks and structure	Clear separation of tasks	Separation of tasks, need for co-working	Potential issues with fans or those intoxicated		
First Aid	Comms for incidents, radios, separation of tasks	Liaison if needed through organisers	Clear roles and responsibilities, radios	Clear separation of tasks	High acceptance		
Staff	Clear tasks and line of communications, radios	Liaison through organisers	Clear separation of tasks	Clear roles and responsibilities, radios	potential issues with those who are intoxicated		
Security	Clear tasks, radios, clear line of communications	Radios, liaison in control room	Radios, clear separation of tasks	Clear roles and responsibilities, radios	Potential issues with those who are intoxicated		
Audience	Personal contact, big screen, online	Medium acceptance	High acceptance	Medium acceptance	Potential issues with those who are intoxicated	Potential clashes. rivalry and intoxication	

- Exeter Food and Drink Festival (2015). [online] Available at: www.exeter-foodanddrinkfestival.co.uk [Accessed 19 June 2015].
- Exeter Phoenix. (2013). Big Screen in the Park. [online] Available at: www.exeter-phoenix.org.uk/big-screen-in-the-park/ [Accessed 20 June 2015].
- Green, C. & Chalip, L. (1998). Sport Tourism as the Celebration of Subculture. *Annals of Tourism Research*. 25(2). 275–291.
- Hatfield, V. (2015). Exeter City Council Tourism Officer. Personal Communication.
- Heart of Devon (2006). Exeter Visitor Strategy 2007–2010. [Online] [http://www.heartofdevon.com/xsdbimsgs/EXETER_VISITOR_STRATEGY_2007-10\[1\].pdf](http://www.heartofdevon.com/xsdbimsgs/EXETER_VISITOR_STRATEGY_2007-10[1].pdf) [Accessed 29 June 2015].
- Heart of Devon (2015). Exeter Fanzone. [Online] Available at: <http://www.heartofdevon.com/exeter/exeter-fanzone> [Accessed 21 June 2015].
- Helbing, D. & Mukerji, P. (2012). Crowd disasters as systematic failures: analysis of the Love Parade disaster. *EPJ Data Science*. 1(7). 1–40.
- Henderson (n.d.). Fan Behaviour – A World of Difference. [Online] Available at: <http://pc.parnu.ee/~htooman/EuroChrie/Welcome%20to%20EuroCHRIE%20Leeds%202007/EuroCHRIE%20Leeds%20Conference%20Preceedings/Full%20Papers/Henderson,%20Stephen.pdf>
- National Rail Enquiries (2015). Live Departures. [Online] <http://ojp.nationalrail.co.uk/service/ldbboard/arr/EXC> [Accessed 25 June 2015]
- Rutherford-Silvers, J. (2008). *Risk Management for Meetings and Events*. Oxon: Routledge.
- Stagecoach Exeter (2015). Exeter Network Route Map. [Online] Available at: <https://www.stagecoachbus.com/uploads/exetermap.pdf> [Accessed 25 June 2015].
- Tum, J., Norton, P. & Nevan Wright, J. (2006). *Management of Event Operations*. Oxford: Butterworth-Heinemann.

Manon Gijbels – Dordrecht, analysis of the weekly market

About Manon

Manon Gijbels is a fourth-year International Tourism Management student at Breda University of applied science in The Netherlands. The tourism industry is fascinating to her, because of her own fondness for travel. During her last year of studies, she participated in a minor Crowd Safety in Hubs and Events because of an interest in understanding the causes of crowd incidents/accidents. Moreover, a willingness to understand the management that goes on behind the screens of an event. Once graduated, she is eager to start her career and excited to broaden her horizon. A future career goal being to work in the field of crowd safety and to contribute to a future in which “the safety of the people is the highest law”.

Introduction

The COVID-19 pandemic has changed the way people go about their daily lives drastically. Just going to the store is almost an event on itself and one must even take the necessary precautions before walking into a store. The weekly market in Dordrecht has also had to adapt to the virus and has put some measures in place to ensure crowd safety. The Sarisgang will be analysed for this essay, as this is a busy street where people tend to find it difficult to follow the guidelines. The four-core modelling elements will be implemented to get a better understanding of the crowd safety at this location and an advice will be provided based on the outcome.

The stands are set up on the Statenplein and Sarisgang, and the market takes place every Friday and Saturday. The market lasts on Friday from 08.00 to 16.00 and on Saturday until 17.00. On the Statenplein the focus is mainly on foodstuffs and on the Sarisgang it is used to be more on consumer goods such as fabrics, care products and flowers (Dordrecht Marketing, 2021).

There are currently rules set in place at the market to guarantee that people obey the COVID-19 regulations, shown on the street furniture. These were introduced after a seven-week absence that was decided upon by Wouter Kolff, chairman of the security region Zuid-Holland Zuid, who called for an emergency order to close all markets (van Driel, 2020). Besides the rules for visitors, there were also new guidelines put in place for the market traders. Only those who sell primary food are allowed a spot on the market. Moreover, each trader has only three stalls available. That way, there is enough space left on the market to keep distance from each other (van Driel, 2020).

People are obliged to follow the regulations on the market, as visible in figure 1, but field research clearly showed that these rules are not respected. The pictures below show what the current situation is like when it comes down to the routes that people take. The satellite picture shows the market set-up before COVID-19; in the current situation all stands have been pushed back towards the Specsavers (North) facing the Pandora (South), meaning that all people walk on the right side of the street.

RAMP analysis

A RAMP analysis stands for the Routes, Areas, Movement and Profile of the crowd at an event. This analysis is performed while evaluating and designing an event location under normal and emergency conditions (Still G. K, Introduction to Crowd Science, 2019). This analysis is based on the weekly market on the Sarisgang in Dordrecht and will highlight the bottlenecks. Moreover, it is mostly based on inhabitants of Dordrecht visiting the market as tourism is low due to the pandemic (Onderzoekcentrum Drechtsteden, 2020).

Routes – the directions that crowds take to get to the site, move around the site and leave the site. These routes should have enough space for people to safely ingress, circulate and egress the location. Moving around the site occurs only on the Sarisgang and Statenplein itself. The Sarisgang/ Statenplein can be reached via the Bagijnhof, Vriesestraat, Statengang and Kolfstraat.

This is the Sarisgang (Figure 60), the street where the weekly market takes place in the city centre of Dordrecht. The circulation experiences counter flows and a lot of streets for an additional number of people to enter or leave the location which results in more routes. The circulation on the market depends on which stands people are looking to visit.

Figure 61 (left) is the route that people take to get to the market, via the Bagijnhof, when arriving by public transport from the Central Station, where both the train and busses stop. This route is almost one straight line and how most people enter and leave the city. Moreover, this route is recommended by the VVV for tourists to enter the city centre of Dordrecht (Dordrecht Marketing & Partners, 2020). The Vriesestraat (Figure 61 – middle) is mostly used by people coming from other neighbourhoods in Dordrecht, such as Vogelbuurt. Moreover, those that want to cut-off the beginning of the market can take this route as it requires less effort, from the station, instead of taking the Bagijnhof. The Statengang (Figure 61 – right) is a narrow street that is not used often to enter the city and market. People going to the Wijnstraat, where most stores are located, to continue their visit are likely to egress the market through here.

Visitors of the city centre can park close by in the parking garage on the Korte Kolfstraat. They enter and leave the market through the Kolfstraat.

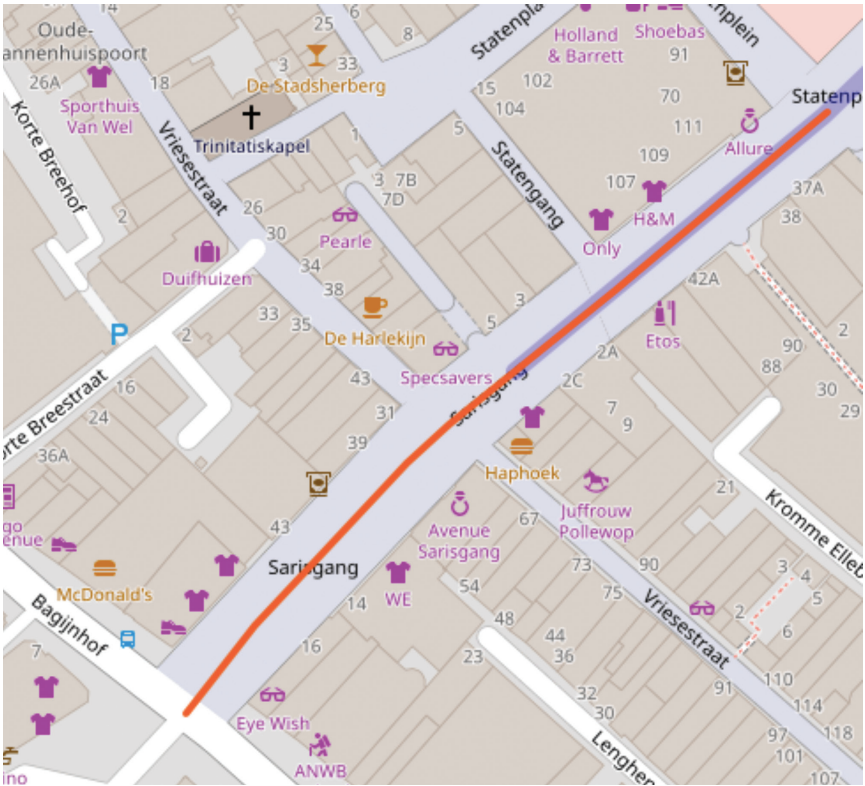


Figure 60 Sarisgang, Weekly market

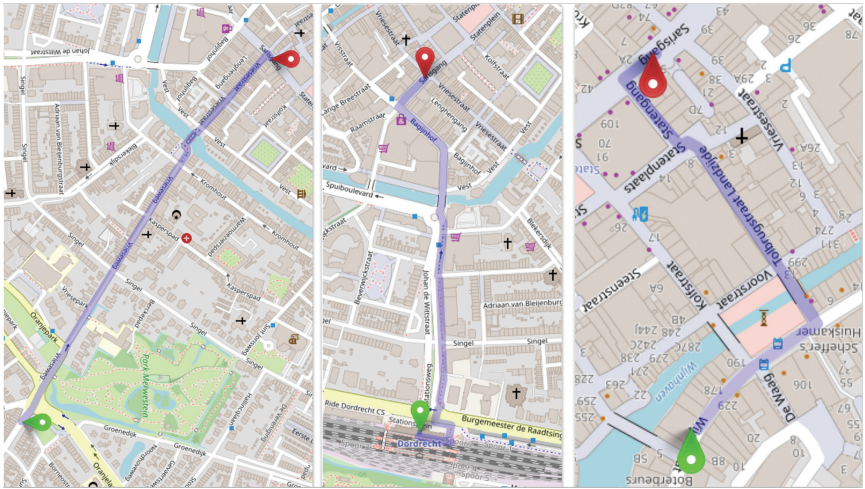


Figure 61 Route to Sarisgang, the Bagijnhof, the Vriesestraat and the Statengang

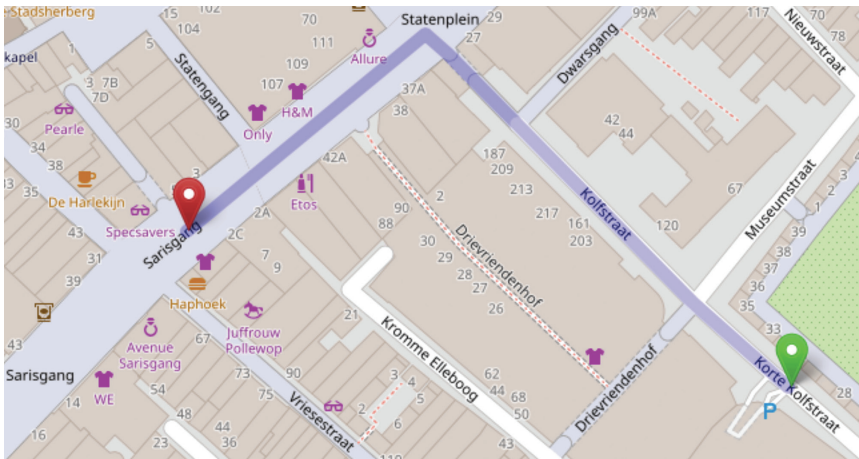


Figure 62 Parking – Korte Kolfstraat

Areas – the locations of crowd density and risks on the site relating to those locations.

The market area is approximately 2,763 square metres, including the space that stands occupy. Currently, it is set up with all market stands being around 4m from the façade on the left side. As seen below in Figure 63, the Sarisgang has been divided into three zones: back of the market stands (1), right in front of the market stands (2) and in front of the façade (3), so moving from top to bottom. A safety margin is implemented, as desk research showed people walking with strollers, walkers and bikes resulting in more square metres per person.

Most of the people move in front of the stands, where there is enough space, but some also try to quickly bypass the crowd on the backside of the stands (zone 1). Zone 1 has a width of only 4m, which frequently sees crossflows, resulting in it being impossible to follow the COVID-19 rules like keeping a 1.5-m distance.

This zone is a dynamic space where people are predominately moving. Zone 1 is $166\text{m length } 4\text{m width} = 664\text{ m}^2$. People take up more space as they are moving; this comes down to 4.7 square metres and a capacity of 0.21 persons per square metre due to COVID-19 regulations (Schaap, 2020). This means that zone 1 has a capacity of $(664\text{ m}^2 : 4.7\text{ m}^2) = 141\text{ persons}$. A safety



Figure 63 Market areas

margin of 20% is implemented which is a capacity of 113 persons in zone 1. As one person needs 4.7 square metres to safely keep distance from all sides, only one-way traffic would be possible which is currently not the case.

An average adult, in a static space, needs an area of at least 3,55 square metres to keep a distance of 1.5 meter to all people that are near-19. This results in a maximum crowd density of 0.28 persons per square metre ($0.28 \text{ m}^2 \cdot 3.55 \text{ m}^2 = 0.994 \text{ persons}$) (Bardy, 2020). Zone 2, where people queue in front of the market stand, is $123 \text{ m length} \times 3 \text{ m width} = 369 \text{ m}^2$. This is a static place with a capacity of $369 \text{ m}^2 \cdot 0.28 \text{ persons/m}^2 = 104 \text{ persons}$. Safety margin results in 83 persons that can securely queue while following guidelines.

Zone 2 also consists of people walking right behind those that are queueing. The area is $160 \text{ m length} \times 4 \text{ m width} = 640 \text{ m}^2$ and it has a capacity of $640 \text{ m}^2 \cdot 0.28 \text{ persons/m}^2 = 179 \text{ persons}$.

Another safety margin: 109 persons.

Zone 3 is a green strip as this part of the street is not used often, so the whole site is not fully utilised. This zone is green as the crowd density is two people per square metre or less: low risks to the crowd (Still, 2019). Zone 3 $160 \text{ m length} \cdot 3 \text{ m width} = 480 \text{ m}^2$. This is more a static space, where people are waiting or standing to the side, the capacity here is $480 \text{ m}^2 \cdot 0.28 \text{ persons/m}^2 = 135 \text{ persons}$. Again, with a safety margin, this is 108 persons.

The total capacity of the market during COVID-19 times would be 413 persons. The terms in the book of Still G. K. (Introduction to Crowd Science, 2019) would call all three zones green and low risk as the crowd density is less than 2 people per square metre, but field research clearly showed the difficulty people faced with keeping a safe distance, even on this big a location.

Movement – rate of passage through various parts of the system.

The movement on the market is dependent on the curiosities of the visitor as they will visit the stands that they are interested in. The peak of movement is in the afternoon from 13.00 to 15.00. Moreover, it has gotten almost busier during the pandemic as some visitors feel it is better to do your shopping on the market, which is “healthier” than in a small and dense supermarket (Westland, 2020).

The optimal flow rate for zone 1 would be challenging as there are no regulations for counter flows and converging routes coming from the Vriesestraat and/or Statengang. Flow rate for zone 2+3 is 10 m, yet these zones due clash in multiple ways as it is both a static and dynamic space. Moreover, there are again counter flows and converging routes from the same streets. The flow rate of the three zones is significantly higher than the capacity of the market during the pandemic. This is also because these COVID-19 regulations and people with walkers and strollers have not been considered.

The mayor of Dordrecht commented that the weekly market follows regulations and is not too busy during the mornings, but a lot of people still see it as an event which results in too much movement during the afternoon (Groeneweg, 2020). Field research confirmed these remarks that show a clear peak in the afternoon.

Table 52 Flow Rate for the Market

FRIDAY	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
Zone 1									
Zone 2									
Zone 3									

Green: less than 50%	
Orange: 50%. 80%	
Red: 80% or more	

This is the expected modal split for the weekly market in Dordrecht. The modal split involves separating (splitting) the predicted trips from each origin zone to each destination zone into distinct travel modes, e.g., walking, bicycle, car, train and bus (Voerknecht & van Bokhorst, 2018 – Chapter 15: Mode Split, 2014). This split is based on the number of trips per inhabitant per mode in Dordrecht which will be user basis.

Profile – the known behaviour of a crowd. There is little analytical data available on visitors of this market, so the profile will be based on the citizens of Dordrecht. The tourists will again not be considered as tourism is low currently.

A study by Esselink et al. (2018) shows that those aged 55 years and older visit a market more frequently; the market has an older visitor profile. Market orientation among young households without children is low. Most market stands sell products like fish, vegetables and meat, so more for people that have a household to go shopping for. Moreover, as most youngsters do not necessarily have to buy groceries, they currently have fewer reasons to visit.

The age group of 55–79 years old represents at 28% with the male/female ratio being 49.51 versus 50.49% in Dordrecht (Onderzoekcentrum Drechtsteden, 2020). This group is part of the baby boomers, born between 1946 and 1964, and is the wealthiest age group of the century (Centraal Bureau voor de Statistiek, 2012). Field research confirmed these numbers as it showed older people, some with walkers and mobility scooters, which affects the planning phase as it impacts the evacuation and, for example, density at an event. It also showed that peak times are always in the afternoon which is something that should be considered for the future.

DIM-ICE risk modelling

A DIM-ICE model (Design, Information, Management – Ingress, Circulation, Egress) is a template that allows the user to compare the diverse behaviour of a crowd and to relate it to the different phases of an event. This delivers a matrix that can be used to evaluate how these crowds would react under normal and emergency situations (Still GK, 2016). The RAMP highlighted the hazards that can occur during both situations.

As visible in the DIM-ICE, most difficulties occur during the circulation phase when both market employees and visitors are walking right past each other. There is some pre-event available on the marketing website of Dordrecht, but nothing regarding COVID-19 measures. There are signs that tell people what the rules are on the market, such as not eating food or not taking bikes, but field research showed that these measures were not obeyed most of the time. Market traders also did not seem to care about the rules as customers were not told off when eating in front of their stand. As can be read, most risks occur due to the pandemic.

The emergency DIM-ICE shows quite some difficulties as the current design has barriers in place so that random vehicles cannot drive onto the market. Nevertheless, this also makes it more difficult for emergency vehicles to reach the location.

The area is big enough and has enough streets that can be used for evacuation but as no police is available on site, visitors will probably need to fend for themselves. Moreover, these streets are filled with bikes as these are not allowed on the market. The management that is available are the market employees who could only do so little with limited knowledge.

Table 53 DIM-ICE Normal

<i>Normal</i>	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Design (Capacity, area, building, barriers)	Suitable width provided for ingress, Street used have stripes for division, Bikes everywhere that block the streets	Wide event area, Lay-out clashes, No one-way traffic; people walk right through and past each other, No stripes for division, Pinch-point zone 1 provides potential risks	Suitable width provided for egress, Streets used have stripes for division, Bikes everywhere that blocks the streets, People walking on the right to egress and those waiting at a stand hinder each other
Information (Signage, PA, media)	Some pre-event information available, Information provision through signage when entering onto the market	No more information provision once on the Sarisgang	Information signage also visible when leaving market
Management	No police visible on site, Staggered arrival profiles	No police visible on site, Market employees do not feel responsible for checking customers on measures, Market employees do not follow rules of market, eating at site	No police visible on site

Table 54 DIM-ICE Emergency

Emergency	Ingress	Circulation	Egress
Design (Capacity, area, building, barriers)	Difficult access for emergency vehicles because of barriers, Bikes everywhere that could block streets	Pinch-point zone 1 provides potential risks, High density area, enough space to evacuate	Difficult access for emergency vehicles because of barriers, Bikes everywhere that could block street
Information (Signage, PA, media)	Some pre-event information available, no emergency signage, no way to distribute emergency information before arrival	No more information provisions once on the Sarisgang, Emergency information can only be distributed through employees or police	No emergency signage
Management	No police visible on site, Market employees could provide limited assistance	No police visible on site, Market employees could provide limited assistance	No police visible on site, Market employees could provide limited assistance

Zone 1 is a small space where there is a high-risk potential with difficulty to evacuate.

Risk mapping

Risk mapping is an assessment form that clearly identifies where crowd density could occur, based on location, duration and severity during the different times (Still G. K, Introduction to Crowd Science, 2019). All three phases are kind of intertwined when analysing a market as there is no specific entrance time that people obey. Everybody comes and goes as they like resulting in the phases overlapping each other throughout the day.

Figure 65 (left) shows the risks during **ingress**, which is expected that people will gradually enter from 11.00 onwards. The Kolfstraat, Vriesestraat and Bagijnhof are often used to ingress onto the market. Yet, the only street that has potential risks is the Vriesestraat as it is quite narrow and is commonly used for people to park their bikes. This in turn makes it more difficult to keep your distance. The market itself is coloured green as it is not too busy before noon.

Figure 64 (middle) shows the risks that there are during the **circulation** phase in the afternoon. Most people have already entered the market and are roaming around. The bigger crowd results in more risks in both zones 1 and 2. The threat exists here for a longer period of time. The surroundings streets are also coloured as the phases can overlap.

Figure 65 (right) shows that **egress** could potentially see difficulties in the Vriesestraat, Statengang and Kolfstraat. The Vriesestraat is again narrow and can be quite busy which makes it difficult to keep a distance.

The Statengang faces this same problem. The Kolfstraat is where the parking garage is situated, so it also has cars on this street which could lead to risks when cars and those egressing the market meet. The back of the stands could be busy with people trying to bypass those in front.

Decision support analysis

Using the matrix approach allows mapping out of one set of variables (congestions, weather and attraction) against another (merchandise stands and bars) and to colour the table to indicate the potential of congestion occurring. Green means less than 50% of the specific area’s capacity, orange indicates between 50% and 80% and red to indicate more than 80% (Still GK, 2019). This decision support matrix maps out the different weather conditions against the three zones that are on the market.

Zone 1 partially has a small overhang which people stand under to be shielded from the rain or sun. Moreover, as this is a tight space that is only 4 metres wide the potential of overcrowding is bigger. With the current

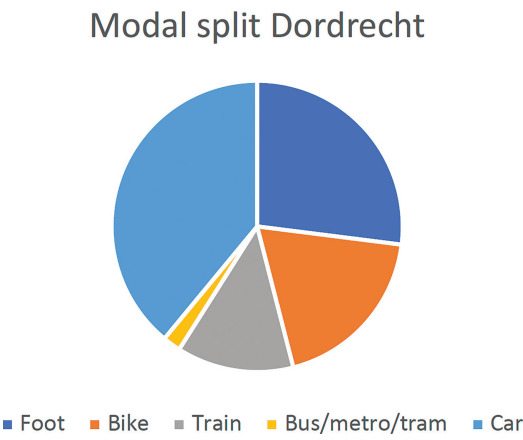


Figure 64 Modal Split



Figure 65 Risk/Congestion Maps, Ingress; Circulation, Egress

Table 55 Decision Support Matrix

<i>Meta Model for Potential Crowd Congestion</i>					
	Zone 1		Zone 2		Zone 3
Hot/sunny					
Overcast					
Cold					
Rain					
High risk		Medium risk		Low risk	

pandemic this could easily result in being not being able to keep their distance. The overhang is smaller than in zone 3 which is why it has only been coloured orange and not red.

Zone 2 does not deal with the effects of the weather as there are no overhangs or ways to shield yourself from the weather. Moreover, as the Dutch are kind of used to the cold it is not that people are too driven to get away from it.

Zone 3 also has a small overhang which people can stand under when it is raining or very sunny. It is a small area which could quickly lead to a potential crowd congestion resulting in people not staying 1.5 metres apart.

Conclusion

The four core modelling elements highlighted the problems lying in wait at the current situation of the weekly market in Dordrecht. My advice for the city is to make changes, some small, in the design, information and management phases. It may seem as though they are doing their COVID-19 “duty” while there are risks that do not necessarily have to be present.

Design – on the market the COVID-19 design creates more space for people to walk in front of the stands, but a pinch-point has now been created behind the stands. It would be better to close off this section and only allow market traders access during the lockdown, as people walk right by each other, and the measures cannot be respected.

In front of the stands people were just casually strolling the market without thinking about the measures. An idea would be to introduce one-way traffic in front of the stands which can be communicated with a division through floor marking. This can be an extra reminder which is certainly not an unnecessary luxury.

Bicycles are not allowed on the market but are now being parked just before entering in the Vriesestraat or Kolfstraat, for example. These take up space that people need to keep their distance and also to safely evacuate in case of an emergency. An extra bicycle storage could be introduced in front of the HEMA, far enough from the entrance of the market.

Information – there is enough information when people enter the market but there are no reminders. Market traders could be asked to put those on their stands, or the city could place more signage on the market itself.

Moreover, the marketing website of Dordrecht contains information on the market, but there is no mention of the rules that are currently in place. It is advisable to include these there as well, as it informs people about the contemporary situation, and they will be prepared.

Management – there was no management in sight on the market to help or assist in case of an emergency. Also, as the rules are not respected much it is wise to have police roam the market. Also, one of the rules is that eating is not allowed on the market, but the majority of the market traders sells food to-go which leads to people consuming this while walking the market. Market traders or police should point out to those people that eating is not allowed on the market.

The weekly market is a great way for people to safely go shopping during this pandemic, but the current set-up does not adhere to the national measures set-up to help reduce the spread of the virus.

REFERENCES

- (sd). Opgehaald van Health and Safety Executive: <https://www.hse.gov.uk>
- (2019). In K. G. Still, *Introduction to Crowd Science* (pp. 2–5). Boca Raton: Taylor & Francis Group.
- Ahoy Rotterdam. (sd). Veelgestelde vragen. Opgeroepen op January 8, 2021, van Ahoy: <https://www.ahoy.nl/informatie/veelgestelde-vragen>
- Association, M. T. (2014, January 1). Veiligheidseisen International Monster Truck Racing Association. Opgehaald van Instituut Fysieke Veiligheid: <https://www.ifv.nl/kennisplein/evenementenveiligheid/publicaties/veiligheidseisen-international-monster-truck-racing-association>
- Bardy, M. (2020, May 25). Covid-19: Space Requirements & Crowd Density. Opgehaald van Siflux: https://www.siflux.com/wp-content/uploads/2020/05/Covid19_space_density.pdf
- BBC. (2017, September 19). Computer simulation. Opgehaald van BBC: <https://www.bbc.co.uk/bitesize/guides/zvxp34j/revision/3>
- Centraal Bureau voor de Statistiek. (2012). *Babyboomers*. The Hague: Centraal Bureau voor de Statistiek.
- Chan, S., & Smith, R. (2017, May 22). Ariana Grande Manchester Concert Ends in Explosion, Panic and Death. Opgehaald van The New York Times: <https://www.nytimes.com/2017/05/22/world/europe/ariana-grande-manchester-police.html>
- Chapter 15: Mode Split. (2014). Opgehaald van <https://www.icpsr.umich.edu/CrimeStat/files/CrimeStatChapter.15.pdf>
- Cicero, M. T. (45BC). *De Legibus*. Roman Republic.
- Cigna. (2016, March). Coping with Fear of Violent Attacks and Terrorism. Opgehaald van Cigna: <https://www.cigna.com/individuals-families/health-wellness/coping-with-fear-of-terrorism>

- Computer simulation. (2017, September 19). Opgehaald van BBC: <https://www.bbc.co.uk/bitesize/guides/zvxp34j/revision/3>
- Coping with Fear of Violent Attacks and Terrorism. (2016, March). Opgehaald van Cigna: <https://www.cigna.com/individuals-families/health-wellness/coping-with-fear-of-terrorism>
- Dijk, R.-J. v. (2020, October 27). Mobility. Breda, The Netherlands.
- Dordrecht Marketing & Partners. (2020). Stadsplattegrond Dordrecht. Opgehaald van Centrum Dordrecht: <https://centrumdordrecht.nl/plan-je-bezoek/stadsplattegrond-dordrecht/>
- Dordrecht Marketing. (2021). Weekmarkt Statenplein & Sarisgang. Opgehaald van Centrum Dordrecht: <https://centrumdordrecht.nl/locatie/weekmarkt-statenplein-sarisgang/>
- Drama bij evenement Haaksbergen. (2014, September 28). Opgehaald van RTL Nieuws: <https://www.rtlnieuws.nl/nederland/artikel/1624806/drama-bij-evenement-haaksbergen>
- Drama monstertruck Haaksbergen: vergunning gemeente onrecht. (2015, October 28). Opgehaald van RTL Nieuws: <https://www.rtlnieuws.nl/node/893851>
- Esselink, R., Lenderink, T., & Nijenhuis, H. (2018, May). De Marktbezoeker. Opgehaald van Centrale Vereniging voor de Ambulante Handel: <https://www.cvah.nl/de-marktbezoeker/>
- Ferrari, C. (2019, March 22). Vergunning aanvragen voor je evenement – een handig stappenplan. Opgehaald van eventbrite: <https://www.eventbrite.nl/blog/vergunning-aanvragen-evenement-ds00/>
- Forsyth, D. R. (2014). Group Dynamics. Belmont: Wadsworth Cengage Learning.
- Gebrek aan alertheid bij vergunning monster truck in Haaksbergen. (sd). Opgehaald van Onderzoeksraad voor veiligheid: <https://www.onderzoeksraad.nl/nl/page/6913/gebrek-aan-alertheid-bij-vergunning-monster-truck-in-haaksbergen>
- Groeneweg, J. (2020, May 4). Dordtse weekmarkt grotendeels goed verlopen: 'Maar sommigen zagen het toch als een uitje'. Opgehaald van AD: <https://www.ad.nl/dordrecht/dordtse-weekmarkt-grotendeels-goed-verlopen-maar-sommigen-zagen-het-toch-als-een-uitje~a0fe9eac0/>
- Hart van Zuid. (2020). Compleet vernieuwde busterminal Zuidplein. Opgeroepen op January 8, 2021, van <https://www.ahoy.nl/informatie/veelgestelde-vragen>
- Lieve, M. d. (2018, June 4). Bijna vier jaar na monstertruckdrama doet chauffeur zijn verhaal: "Kon ik het maar terugdraaien". Opgehaald van NH Nieuws: <https://www.nhnieuws.nl/nieuws/225741/bijna-vier-jaar-na-monstertruckdrama-doet-chauffeur-zijn-verhaal-kon-ik-het-maar-terugdraaien>
- Monster Truck Racing Association. (2014, January 1). Veiligheidseisen International Monster Truck Racing Association. Opgehaald van Instituut Fysieke Veiligheid: <https://www.ifv.nl/kennisplein/evenementenveiligheid/publicaties/veiligheidseisen-international-monster-truck-racing-association>
- NOS. (2014, September 30). Vergunning Haaksbergen "routine". Opgehaald van NOS: <https://nos.nl/artikel/704609-vergunning-haaksbergen-routine.html>
- NOS. (2015, February 17). 'Vergunning monstertruck ten onrechte verleend'. Opgehaald van NOS: <https://nos.nl/artikel/2019891-vergunning-monster-truck-ten-onrechte-verleend.html>
- Onderzoekcentrum Drechtsteden. (2020). Bevolking - Dordrecht. Opgehaald van Onderzoekcentrum Drechtsteden: https://ocd.buurtmonitor.nl/jive?cat_open_code=c1

- Onderzoekcentrum Drechtsteden. (2020). Monitor Coronacrisis. Sliedrecht: Onderzoekcentrum Drechtsteden.
- Onderzoeksraad voor Veiligheid. (2015, May 20). Gebrek aan alertheid bij vergunning monster truck in Haaksbergen. Opgehaald van Onderzoeksraad voor Veiligheid: <https://www.onderzoeksraad.nl/nl/page/6913/gebrek-aan-alertheid-bij-vergunning-monster-truck-in-haaksbergen>
- Oozoo. (2020). Wetenswaardigheden, cijfers en statistieken over Dordrecht. Opgehaald van Oozoo: <https://www.oozo.nl/cijfers/dordrecht>
- RET. (2019, February 22). Cijfers metro: Rotterdam Beurs is drukste metrostation van Nederland. Opgeroepen op January 8, 2021, van Treinreiziger: <https://www.treinreiziger.nl/cijfers-metro-rotterdam-beurs-is-drukste-metrostation-van-nederland/>
- RET. (2019). Jaarverslag 2019 RET. Opgeroepen op January 8, 2021, van <https://corporate.ret.nl/media/2899/jaarverslag-2019-ret.pdf>
- RTL Nieuws. (2014, September 28). Drama bij evenement Haaksbergen. Opgehaald van RTL Nieuws: <https://www.rtlnieuws.nl/nederland/artikel/1624806/drama-bij-evenement-haaksbergen>
- RTL Nieuws. (2015, October 28). Drama monstertruck Haaksbergen: vergunning gemeente onterecht. Opgehaald van RTL Nieuws: <https://www.rtlnieuws.nl/node/893851>
- RTV Oost. (2014, September 29). 'Verantwoordelijkheid voor ongeluk Haaksbergen ligt bij gemeente en organisatie' 1200 kbps geselecteerd als afspeelkwaliteit Veel hulpverleners in Haaksbergen (Foto: Erik Schaddelee) Veel hulpverleners in Haaksbergen (Foto: Erik Schaddelee) Syan S. Opgehaald van RTV Oost: <https://www.rtvooost.nl/nieuws/199444/Verantwoordelijkheid-voor-ongeluk-Haaksbergen-ligt-bij-gemeente-en-organisatie>
- Santayana, G. (1906). Reason in Common Sense.
- Schaap, S. (2015, June 10). GEMEENTEN MOETEN ÉÉN KADER GEBRUIKEN VOOR VEILIGE EVENEMENTEN. Opgehaald van Centrum voor criminaliteitspreventie en veiligheid: <https://ccv-secondant.nl/platform/article/gemeenten-moeten-een-kader-gebruiken-voor-veilige-evenementen>
- Schaap, S. (2020, September 10). Crowd Safety and Risk Analysis. Breda, The Netherlands.
- Spence, S. (2020, October 28). Right-wing extremism: The new wave of global terrorism. Opgehaald van World Economic Forum: <https://www.weforum.org/agenda/2020/10/right-wing-extremism-global-terrorism/>
- Statista. (2019, September). Number of festivals in the Netherlands from 2013 to 2018. Opgehaald van Statista: <https://www.statista.com/statistics/673435/number-of-festivals-in-the-netherlands/>
- Still, G. K. (2013). Introduction to Crowd Science. Boca Raton: CRC Press. Opgeroepen op oktober 14, 2020
- Still, K. G. (2019). Introduction to Crow Science. Boca Raton: Taylor & Francis Group.
- Still, K. G. (2019). Introduction to Crowd Science. Boca Rotan: Taylor & Francis Group.
- Still, K. G. (2019). Introduction to Crowd Science. Boca Raton: Taylor & Francis Group.
- Thalmann, D. (2016). Crowd Simulation. In N. Lee, Encyclopedia of Computer Graphics and Games (pp. 1–8). Springer International Publishing.
- van Driel. (2020, April 29). Markten in Zuid-Holland Zuid weer toegestaan, maar wel onder extra toezicht. Opgehaald van AD: <https://www.ad.nl/dordrecht/markten-in-zuid-holland-zuid-weer-toegestaan-maar-wel-onder-extra-toezicht-aa6efc74/>

- van Driel. (2020, April 30). Nieuwe regels tijdens de Dordtse weekmarkt: 'Houd afstand en blijf niet langer dan nodig'. Opgehaald van AD: <https://www.ad.nl/dordrecht/nieuwe-regels-tijdens-de-dordtse-weekmarkt-houd-afstand-en-blijf-niet-langer-dan-nodig~a5b28df5/>
- van Driel, I. (2020, April 29). Markten in Zuid-Holland Zuid weer toegestaan, maar wel onder extra toezicht. Opgehaald van AD: <https://www.ad.nl/dordrecht/markten-in-zuid-holland-zuid-weer-toegestaan-maar-wel-onder-extra-toezicht~aa6efc74/>
- van Driel, I. (2020, April 29). Markten in Zuid-Holland Zuid weer toegestaan, maar wel onder extra toezicht. Opgehaald van AD: <https://www.ad.nl/dordrecht/markten-in-zuid-holland-zuid-weer-toegestaan-maar-wel-onder-extra-toezicht~aa6efc74/>
- van Driel, I. (2020, April 30). Nieuwe regels tijdens de Dordtse weekmarkt: 'Houd afstand en blijf niet langer dan nodig'. Opgehaald van AD: <https://www.ad.nl/dordrecht/nieuwe-regels-tijdens-de-dordtse-weekmarkt-houd-afstand-en-blijf-niet-langer-dan-nodig~a5b28df5/>
- van Driel, I. (2020, April 30). Nieuwe regels tijdens de Dordtse weekmarkt: 'Houd afstand en blijf niet langer dan nodig'. Opgehaald van AD: <https://www.ad.nl/dordrecht/nieuwe-regels-tijdens-de-dordtse-weekmarkt-houd-afstand-en-blijf-niet-langer-dan-nodig~a5b28df5/>
- Vergunning Haaksbergen "routine". (2014, September 30). Opgehaald van NOS: <https://nos.nl/artikel/704609-vergunning-haaksbergen-routine.html>
- 'Vergunning monstertruck ten onrechte verleend'. (2015, February 17). Opgehaald van NOS: <https://nos.nl/artikel/2019891-vergunning-monstertruck-ten-onrechte-verleend.html>
- Vergunst, N. (2020, June 2). Crowd simulation software visualises layout for social distancing. Opgehaald van Utrecht University: <https://www.uu.nl/en/news/crowd-simulation-software-visualises-layout-for-social-distancing>
- Voerknecht, H., & van Bokhorst, M. (2018, March). Benchmark actieve, gezonde, duurzame mobiliteit gemeenten. Opgehaald van CE Delft: https://www.ce.nl/assets/upload/file/Rapporten/2018/4N74/CE_Delft_4N74_Benchmark_actieve_gezonde_duurzame_mobiliteit_gemeenten_DEF.pdf
- Vrie, K. d. (2020, June 21). TIP! - Welke vergunningen heb ik nodig om een evenement te organiseren?. Opgehaald van eventplanner: https://www.eventplanner.nl/nieuws/4569_tip-welke-vergunningen-heb-ik-nodig-om-een-evenement-te-organiseren.html
- Westland, E. (2020, March 13). Druk op de markt na maatregelen corona: 'Iedereen wil wat extra's te eten in huis hebben' Met name eieren zijn vandaag niet aan te slepen op de markt in Kanaleneiland. Foto: RTV Utrecht / Evie Westland Met name eieren zijn vandaag niet aan te slepen op de. Opgehaald van RTV Utrecht: <https://www.rtvutrecht.nl/nieuws/2027385/druk-op-de-markt-na-maatregelen-corona-iedereen-wil-wat-extras-te-eten-in-huis-hebben.html>
- Wijermans, F. E. (2011). Understanding crowd behaviour: simulating situated individual. Groningen: University of Groningen, SOM.

Bert Bruyninckx – bicentenary of the battle of Waterloo

About Bert

Bert is the owner and lead crowd consultant at 360 Solutions Risk and Safety. With over 20 years of experience in the leisure and event industry Bert managed events and mass gatherings of all sizes. Specializing in modelling and managing people flow on a medium or micro scale, where a solid qualitative organization of every step in the visitor journey must ensure the balance between safety, visitor experience and comfort, and economic feasibility. His track record contains not only the usual (mass)event related projects but also museums, amusement parks, public health facilities and other public spaces around the world.

Bert graduated from Manchester Metropolitan University and holds a master's degree in Crowd Safety and Risk Analysis. Next to this, Bert is an experienced Lund University certified crowd simulation engineer. This thorough academic background combined with experience ensures realistic modelling and pragmatic solutions for every crowd related problem.

“Safe qualitative operations for all places of gathering, that's my goal.”

Introduction to the event

Every year reenactors from all over the world assemble in Waterloo, Belgium, to re-enact the famous battle of Waterloo from 1815. In 2015 this event was taken to a higher level because of the bicentenary 1815–2015. For the occasion no less than 6,000 reenactors from 85 different countries gathered at Waterloo. They camped for four days in their 1815's military encampment and operated in two re-enactments of the historical battle. Twenty-four tribunes and two standing areas accommodated about 10,000 patrons on 18th of June and 60,000 ticketholders on the 19th and 20th of June. Besides ticketholders it was to be expected to have an extra group of visitors during the day, people just visiting the encampments or curious passers-by. The macro time schedule and the geographical situation are seen in Figure 65.

For this report I focus on Friday 19th and Saturday 20th of June, when the big re-enactment took place. Ticketholders are a heterogeneous group of all ages and nationalities. Doors open at 18:00, show starts at 20:00 and ends at about 22:30. The plan and photo (Figure 67) illustrate the situation around the battlefield and the tribunes.

RAMP analysis

Routes – Areas – Movement – Profile

Visitors come mostly from the North, South and West; all parkings and public transport are in these directions. Means of travel or parkings are not

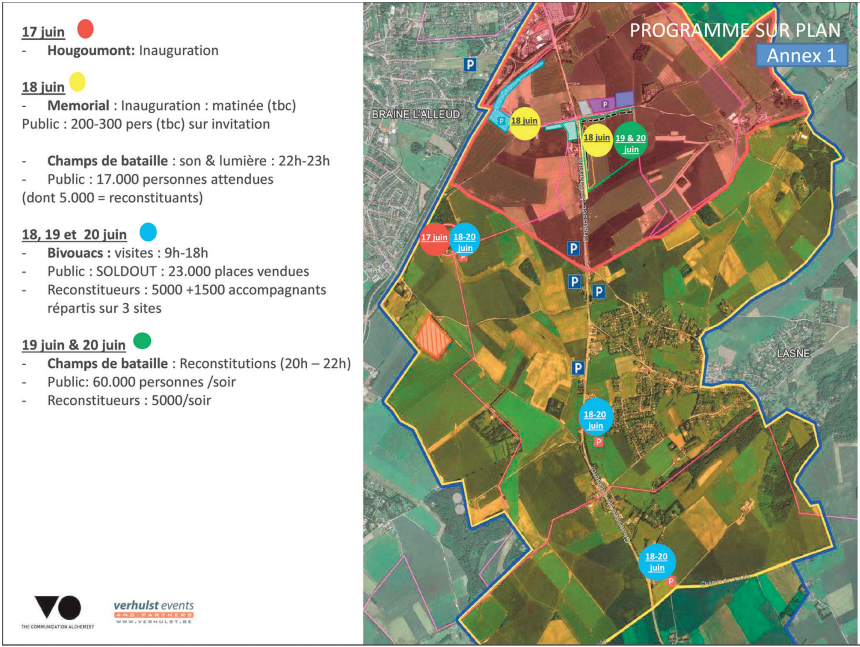


Figure 66 Time schedule and geographic location

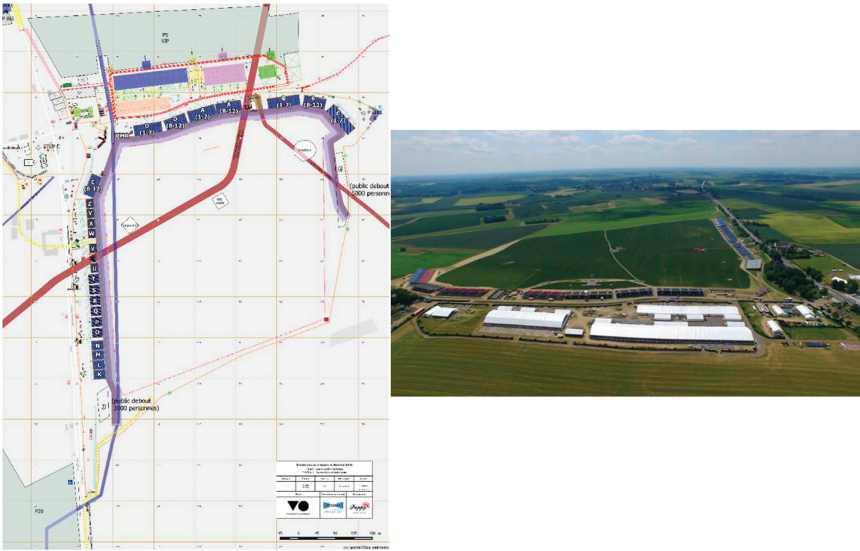


Figure 67 Site plan and aerial image

considered in the assignment¹⁸ of seats. Visitors are likely to cross the main crossroads, further referred to as “Belgium”. Figure 68 shows risk and congestion during ingress and egress.

The main North-South Road, the N5, is kept free off traffic. One lane serves as emergency route for the event in Belgium referred to as “Noria”. “Belgium” is not only an important crossroad for visitors but it is also the only place visitors can cross the emergency route coming from or going to the North and the West. Figure 68 “Noria” (Bruyninckx, N5 Way in/out & Noria, 2015) shows the detailed situation concerning the “Noria” and “Belgium”.

Police controls “Belgium” and closes the crossing for visitors if necessary. Low fences separate the visitor’s lane from the emergency lane. The width of the emergency route crossing at “Belgium” is set on 6 metres. There is a reservoir area at the East side. Figure 70 “Reservoir area” shows the overall situation.

Figure 71 shows the fluxes towards “Belgium” and the detailed crowd flow of the reservoir area.

As there are side activities during the day it is to be expected that ingress will be gradual whilst egress is expected to be more difficult and all at once. Especially “Belgium” will be a hotspot since visitors from both Tribune North and West need to cross the “Noria” leaving to the North and West.

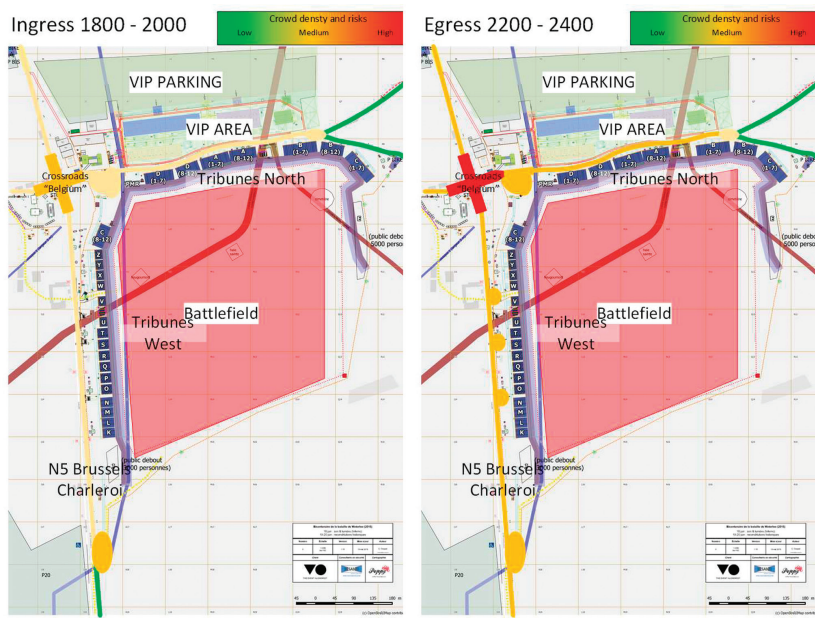


Figure 68 Risk and congestion maps

¹⁸ Tribune is Ditch for Stands/Seating area.

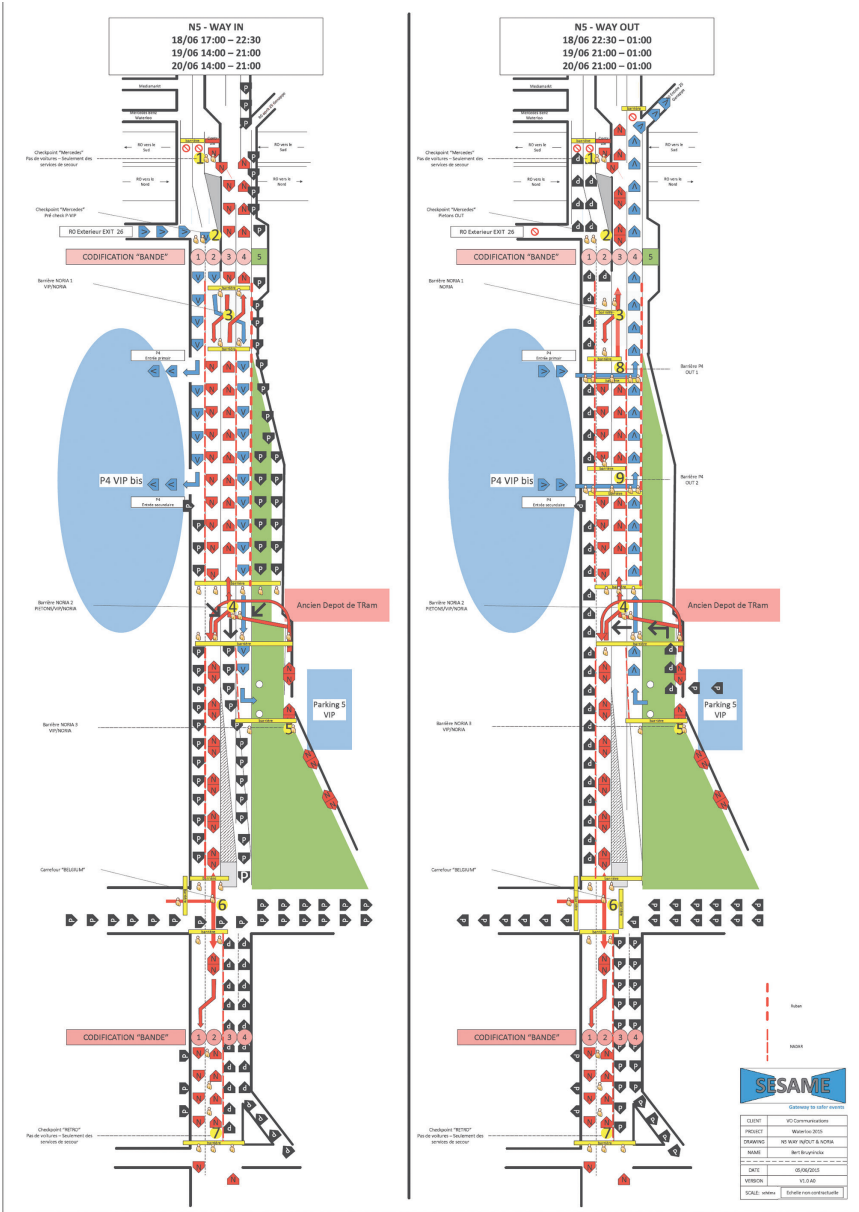


Figure 69 North-South ingress/egress



Figure 70 Image of the reservoir area

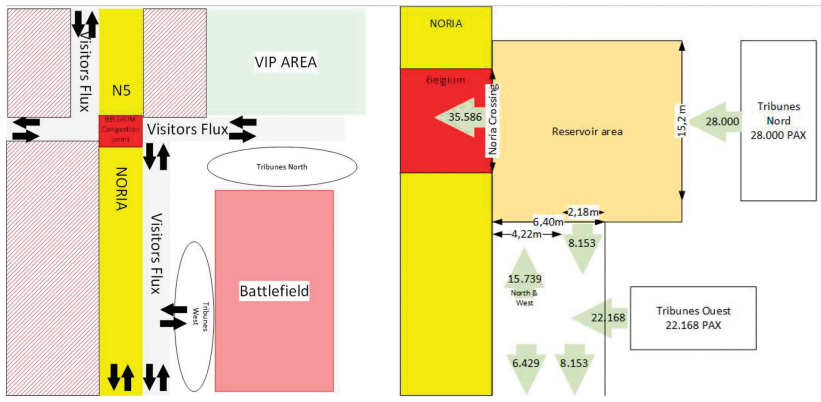


Figure 71 Crowd flow and detail of the reservoir area

DIM-ICE – normal

The DIM-ICE model shown in Table 57-58 is made with the information available in June 2015

Results of the DIM-ICE and RAMP analysis

The DIM-ICE model and RAMP analysis show that the biggest risk is during egress, especially at the crossing of 6 metres at “Belgium”. Egress time and crowd density in the reservoir area are key.

Table 56 DIM-ICE Normal

Normal	Ingress	Circulation	Egress
Design	Roads closed for other traffic. Modal split is known. Parking tickets bought in advance, occupancy is known, ingress will be gradual. Flow directions are known North = 39%, West = 32%, South = 29%. Entrance and crew capacity is calculated per tribune for quick entrance procedure, no logical order in tribunes.	Seats are numbered. Barriers are used to separate pedestrians and vehicles, open terrain. Capacity of facilities are calculated. No separate service way.	Roads are closed for other traffic. Low barriers are used. Immediate total egress. Tribunes are not linked to parking's, flux of visitors in the 3 main directions, all passing "Belgium" and most crossing of the emergency route, the crossing of the emergency route is only 6 metres wide.
Information	All tickets are clearly marked with tribune and seat number, good signage and dynamic led screens at entrees and tribunes. Visitors are asked and advised to come early.	Tribune and facility signage is in place	Signage and dynamic led screens; low barriers are used
Management	Control room with all emergency services, police, government officials, representative of the organisation, Risk advisor(s). CCTV and areal video from police helicopter. Stewards, security and police on site, extra police at "Belgium", hierarchical operational structure. Controlled radio communication network. Fully briefed stewards and security guards. Reenactors same route and possible same time	Stewards on tribunes and public areas directing people. Megaphones at critical points. Security plan developed. Security guards briefed and in place.	Stewards on tribunes and public areas directing people. Megaphones. Security place developed. Security guards briefed and in place. Police control the flux at "Belgium" + supervision of organization Risk advisor. Fully briefed stewards and security guards

Egress time through "Belgium" and density in the reservoir area

To determine whether the set width of "Belgium" is sufficient and how this affects crowd density in the reservoir area and the flow rates in and outside the reservoir area is calculated. Figure 72 shows the different calculated flow rates to determine total egress time for the reservoir area and crowd density in the reservoir area. VIPs are not considered in the calculation. After the spectacle they go to the VIP area behind the tribunes.

Table 57 DIM-ICE Emergency

Emergency	Ingress	Circulation	Egress
Design	Low barriers. Emergency exits in place; parking's are free to leave. Different police positions on site, 2nd VMP and Fire service point. Crossing the emergency route, the crossing of the emergency route, the crossing of the emergency route is only 6m wide.	Low barriers, open terrain, facilities, and emergency exits calculated. Capacity of facilities is calculated. No separate service way.	Immediate total egress. The crossing of the emergency route is only 6 meters wide. Evacuation flux needs to cross the emergency route
Information	Emergency exit signs, dynamic signs (parking), radio/TV	Signage, PA	Led screens directions. Police are on site
Management	Control room with all emergency services, police, government official's representative of the organisation, Risk advisor(s). CCTV and areal video from police helicopter. Liaison of governor present on site. Gold commander present on site. Stewards, police, extra police at "Belgium", hierarchical operational structure. Controlled radio communication network, megaphones. Fully briefed stewards and security guards.	PC Prev, ECC, operational hierarchy, stewards, guards, procedure to stop show.	Stewards, police, extra police at "Belgium", hierarchical operational structure. Controlled radio communication network, megaphones,

The Guide to Safety at Sports Grounds states that on a level surface hundred people can reasonably exit in one minute. This equals to 82 persons per metre width per minute (Department for Culture, Media and Sport, 2008).

To maintain this flow rate crowd density should be kept at a maximum of three people per square metre (Still G. K., Introduction to Crowd Science, 2013). As from three people per square metre, flow rates drop, the flow becomes unstable and risk of congestion arises.

Figure 73 "flux numbers" (Bruyninckx, Schéma Egress, 2015) visualises the set situation, flux directions and available space for the crowd to flow. Crowd numbers are based on actual venue capacity. Destination flow numbers are based on the parking and public transport capacities in the North, South and West.

Actual starting situation: width "Belgium" is set on 6 metres

At a normal egress where 100% of the visitors leave all at the same time or an evacuation scenario the 6 metres width of "Belgium" might be

problematic. It might lead to inefficient egress, long waiting ques and high crowd density in the reservoir area.

The normal flux time through “Belgium”, crowd build-up and crowd density in the waiting area was calculated, based on a 100% egress and the width of “Belgium” being 6 metres.

Figure 74 “Egress time through ‘Belgium’ and crowd density: 6 metres – Pax 100%” calculates flow rates as illustrated in Figures 71 and 72.

Figure 74 shows flow rate per minute on the primary axis. Crowd density per minute is shown on the secondary axis.

Summary of the results

Total egress time for the reservoir area is 73 minutes.

The first 23 minutes’ crowd builds up in the reservoir area.

Crowd density reaches the critical 4 people per square metre (Department for Culture, Media and Sport, 2008) at minute 8. For a total of 51 minutes crowd density is higher than 4 people per square metre.

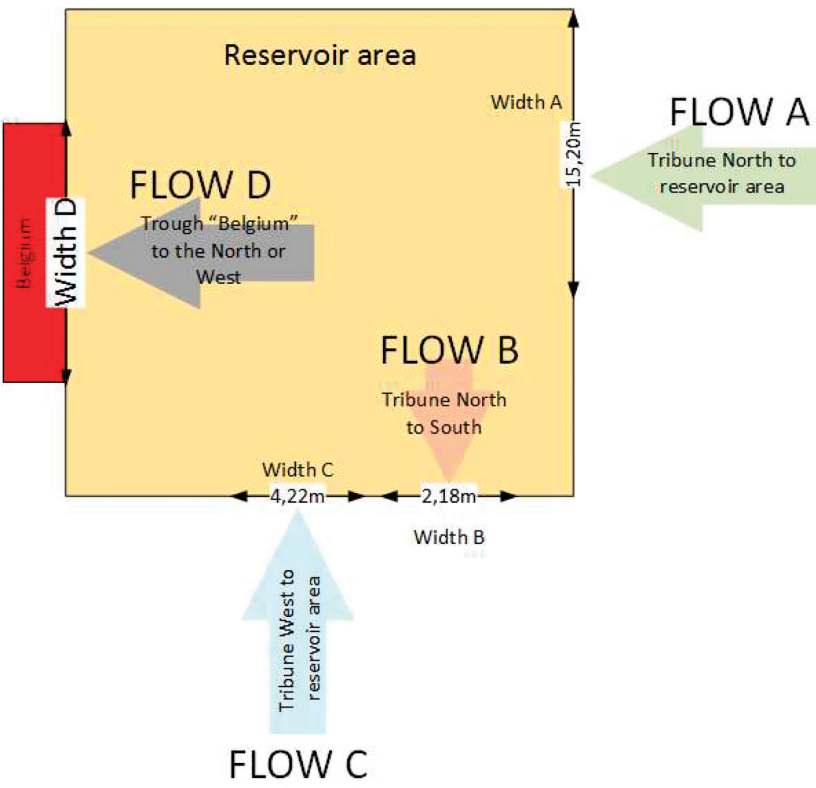


Figure 72 Calculated flow rates

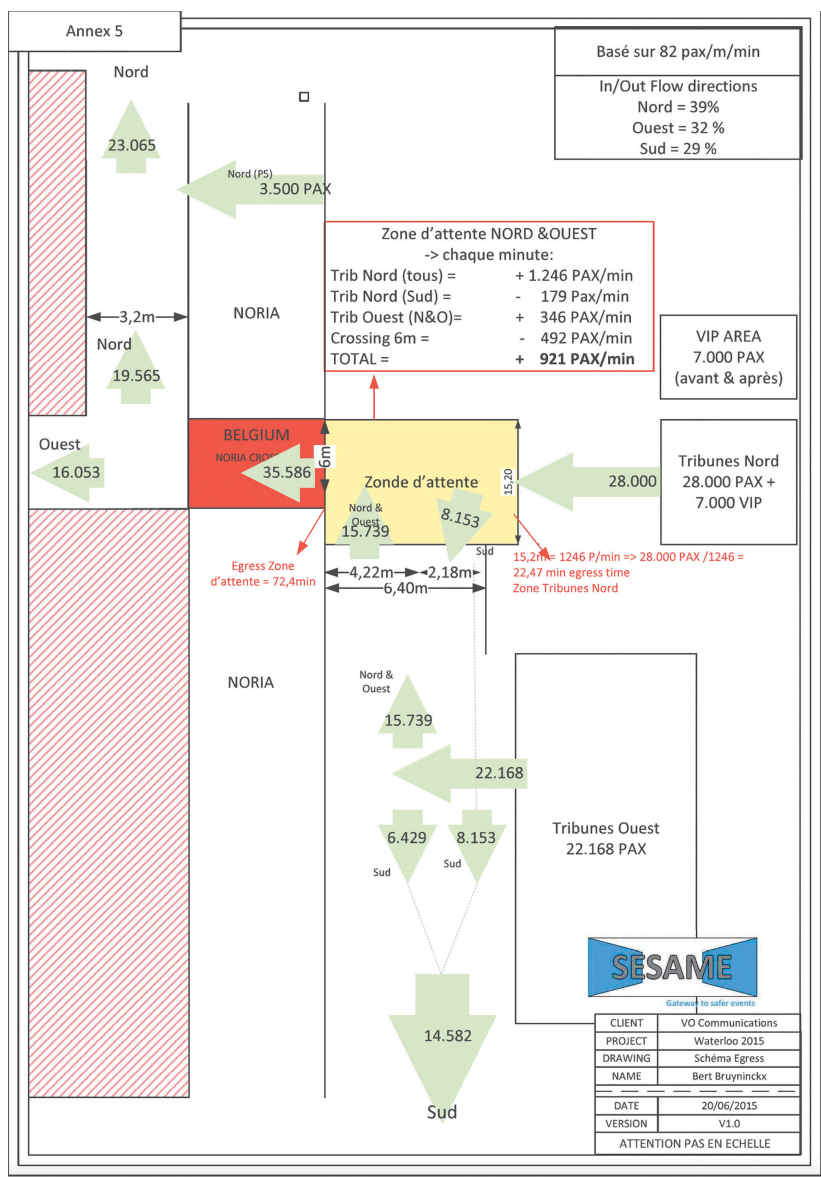


Figure 73 Flux numbers

Above all, the calculation showed that the width of 6 metres is not sufficient to safely exit 100% of the visitors and leads to long waiting times outside the reservoir area.

Recalculation: width “Belgium” set on 10 metres and 75% of visitors.

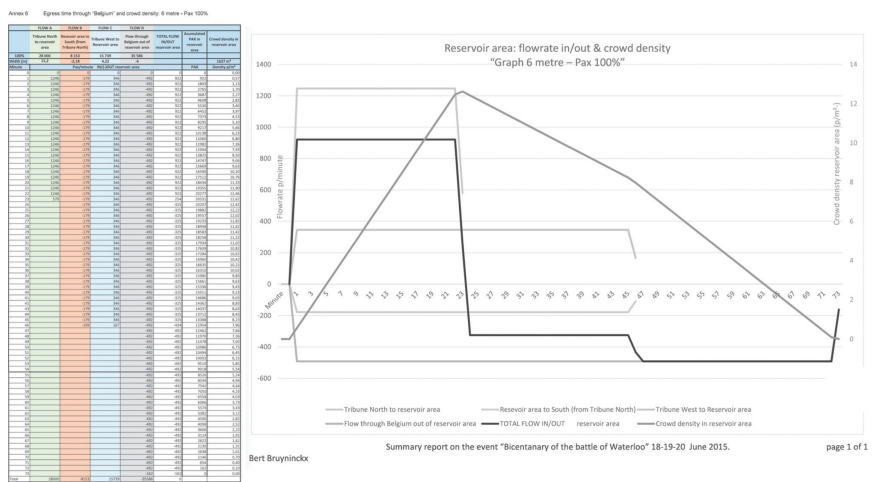


Figure 74 Graph 6 metres. Pax 100%

It was clear that the 6 metres crossing was a problem. As it showed that people were already leaving the venue during the show, calculations were made based on the estimation that 25% of the visitors have left before the end of the show. Width of the crossing was set on 10 metres.

Figure 75 “Egress time through ‘Belgium’ and crowd density: 10 metres – Pax 75%” calculates flow rates as illustrated in Figure 72. Figure 75 “Graph 10 metres – Pax 75%” shows flow rate per minute on the primary axis. Crowd density per minute in time is shown on the secondary axis.

The calculations and graph show:

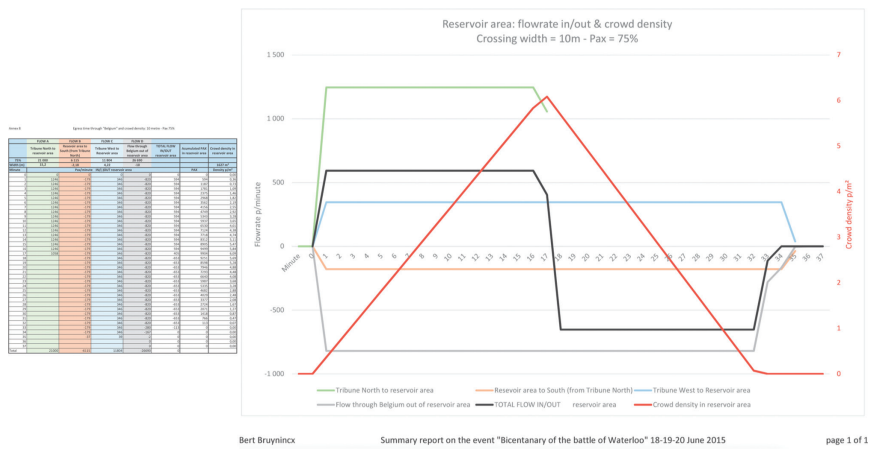


Figure 75 Graph 10 metres. Pax 75%

Total egress time is 35 minutes and the reservoir area is empty from minute 33.

The first 17 minutes crowd builds up in the waiting area.

Crowd density reaches the critical 4 people per square metre (Department for Culture, Media and Sport, 2008) at minute 11. For a total of 11 minutes crowd density is higher than 4 people per square metre.

This will result in queues outside the waiting area.

At the staff meeting with all stakeholders half an hour before the end of show the calculations in Figure 75 were presented. By then it was clear that not all visitors were going to stay till the end so the expected total egress at the end of the show, as noted in the DIM-ICE model, was no longer valid.

Based on the calculations and with the help of the visualizations in the graphs during the meeting width was set on 10 metres. Besides this the passage at “Belgium” was to be visualised with orange stakes attached to the low fences so people could see the route narrows. The crowd density exceeding 4 people per square metre and peaking at 6.09 at minute 17 was allowed since the travel time from the furthest tribune is not considered.

Although this was not an ideal situation, “Belgium” was crowded and crowd density was high, everything went well.

Ideal width: crowd density is max 4 people per square metre.

Although everything went well calculations were made in search of the “ideal” width of “Belgium”. What width should it be to keep crowd density in the reservoir area beneath the upper limit of 4 people per square metre (Department for Culture, Media and Sport, 2008).

In scenario a 25% of patrons leave before the end of the show and calculations are made based on 75% of crowd capacity. Scenario b is based on 100% crowd capacity.

Visitors do not all stay till the end of the show, pax = 75%

To make this calculation the width of “Belgium” was set as variable, crowd density was restricted to maximum 4 people per square metre and 75% of the total crowd capacity is considered.

Figure 76 “Egress time through ‘Belgium’ and crowd density: 12,57 metres – Pax 75%” calculates flow rates as illustrated in Figure 9 considering the restrictions on crowd density. Figure 76 “Graph 10 metres – Pax 75%” shows each flow rate per minute on the primary axis. Crowd density for each minute in time is shown on the secondary axis.

In this scenario the ideal width of “Belgium” is 12.57 metres. In this “ideal” situation”:

- Total egress time is 35 minutes, but the reservoir area is empty after 24 minutes
- The first 17 minutes crowd builds up in the waiting area
- Crowd density never exceeds 4 people per square metre

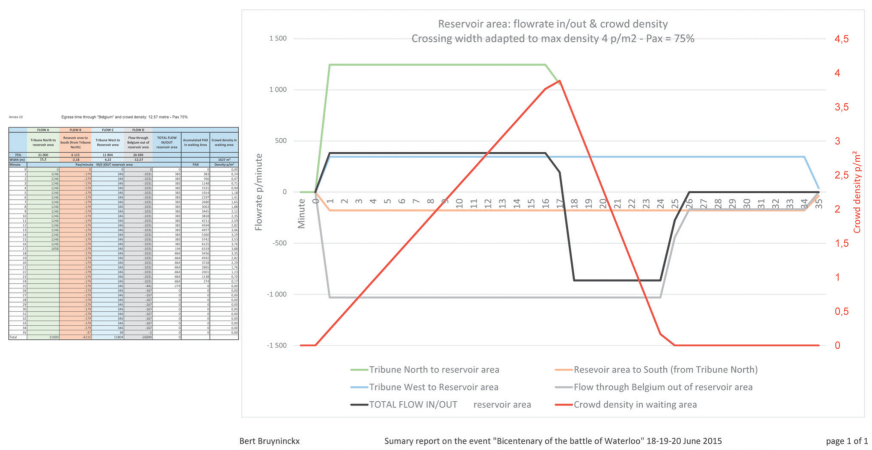


Figure 76 Graph 12.57 metres. Pax 75%

b. Visitors all stay till the end of the show, pax = 100%

To make this calculation the width of “Belgium” was set as variable, crowd density was restricted to maximum 4 people per square metre and 100% of the total crowd capacity is considered.

Figure 77 “Egress time through ‘Belgium’ and crowd density: 13.63 metres – Pax 100%” calculates flow rates as illustrated in Figure 5 considering the restrictions on crowd density. Figure 77 “Graph 13.63 metres – Pax 100%” shows each flow rate per minute on the primary axis. Crowd density for each minute in time is shown on the secondary axis.

In this scenario the ideal width of “Belgium” is 13.63 metres. In this “ideal” situation:

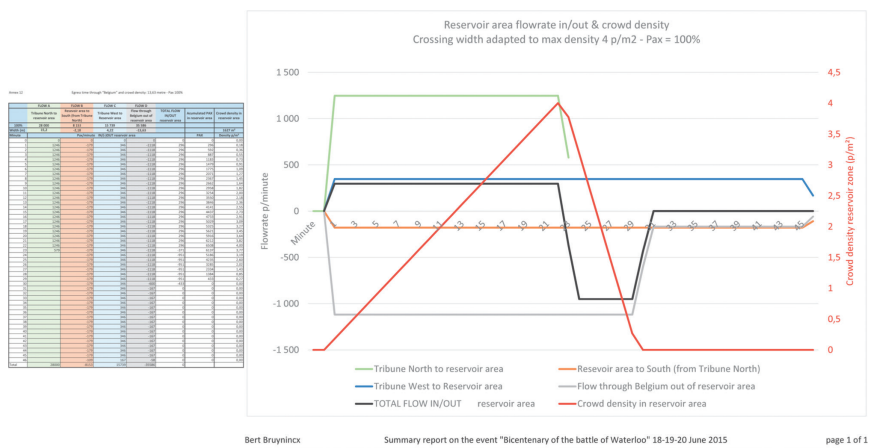


Figure 77 Graph 13.63 metres. Pax 100%

- Total egress time is 46 minutes, but the reservoir area is empty after 29 minutes
- The first 22 minutes crowd builds up in the waiting area
- Crowd density never exceeds 4 people per square metre

Conclusion

From the beginning “Belgium” and “Noria” were the main choke points in the crowd management plan especially during egress. This is also pointed out in the DIM-ICE model. The assumption shared by all stakeholders that egress would not be gradual proved to be wrong. Nevertheless, high crowd density was to be expected at “Belgium”.

With the help of the calculations and graphs shown in Figures 73 and 74 actual changes to the set-up were made. Although this situation was not ideal, the overall risk of overcrowdings during egress was lowered.

REFERENCES

- Bruyninckx, B. (2015). N5 Way in/out & Noria, Aarschot: SeSaME.
- Bruyninckx, B. (2015). Schéma Egress, Aarschot: SeSaME Group.
- Department for Culture, Media and Sport (2008). The Guide to Safety at Sports Grounds (5th ed.). Norwich: Her Majesty's Stationary Office.
- Still, G. K. (2013). Introduction to Crowd Science. Boca Raton: CRC Press.
- (sd). Opgehaald van Health and Safety Executive: <https://www.hse.gov.uk>
- (2019). In K. G. Still, Introduction to Crowd Science (pp. 2–5). Boca Raton: Taylor & Francis Group.
- Ahoy Rotterdam. (sd). Veelgestelde vragen. Opgeroepen op January 8, 2021, van Ahoy: <https://www.ahoy.nl/informatie/veelgestelde-vragen>
- Association, M. T. (2014, January 1). Veiligheidseisen International Monster Truck Racing Association. Opgehaald van Instituut Fysieke Veiligheid: <https://www.ifv.nl/kennisplein/evenementenveiligheid/publicaties/veiligheidseisen-international-monster-truck-racing-association>
- Bardy, M. (2020, May 25). COVID-19: SPACE REQUIREMENTS & CROWD DENSITY. Opgehaald van Siflux: https://www.siflux.com/wp-content/uploads/2020/05/Covid19_space_density.pdf
- BBC. (2017, September 19). Computer simulation. Opgehaald van BBC: <https://www.bbc.co.uk/bitesize/guides/zvxp34j/revision/3>
- Centraal Bureau voor de Statistiek. (2012). Babyboomers. The Hague: Centraal Bureau voor de Statistiek.
- Chan, S., & Smith, R. (2017, May 22). Ariana Grande Manchester Concert Ends in Explosion, Panic and Death. Opgehaald van The New York Times: <https://www.nytimes.com/2017/05/22/world/europe/ariana-grande-manchester-police.html>
- Chapter 15: Mode Split. (2014). Opgehaald van <https://www.icpsr.umich.edu/CrimeStat/files/CrimeStatChapter.15.pdf>
- Cicero, M. T. (45BC). De Legibus. Roman Republic.
- Cigna. (2016, March). Coping with Fear of Violent Attacks and Terrorism. Opgehaald van Cigna: <https://www.cigna.com/individuals-families/health-wellness/coping-with-fear-of-terrorism>

- Computer simulation. (2017, September 19). Opgehaald van BBC: <https://www.bbc.co.uk/bitesize/guides/zvxp34j/revision/3>
- Coping with Fear of Violent Attacks and Terrorism. (2016, March). Opgehaald van Cigna: <https://www.cigna.com/individuals-families/health-wellness/coping-with-fear-of-terrorism>
- van Dijk, R.-J. (2020, October 27). Mobility. Breda, The Netherlands.
- Dordrecht Marketing & Partners. (2020). Stadsplattegrond Dordrecht. Opgehaald van Centrum Dordrecht: <https://centrumdordrecht.nl/plan-je-bezoek/stadsplattegrond-dordrecht/>
- Dordrecht Marketing. (2021). Weekmarkt Statenplein & Sarisgang. Opgehaald van Centrum Dordrecht: <https://centrumdordrecht.nl/locatie/weekmarkt-statenplein-sarisgang/>
- Drama bij evenement Haaksbergen. (2014, September 28). Opgehaald van RTL Nieuws: <https://www.rtlnieuws.nl/nederland/artikel/1624806/drama-bij-evenement-haaksbergen>
- Drama monstertruck Haaksbergen: vergunning gemeente onrecht. (2015, October 28). Opgehaald van RTL Nieuws: <https://www.rtlnieuws.nl/node/893851>
- Esselink, R., Lenderink, T., & Nijenhuis, H. (2018, May). De Marktbezoeker. Opgehaald van Centrale Vereniging voor de Ambulante Handel: <https://www.cvah.nl/de-marktbezoeker/>
- Ferrari, C. (2019, March 22). Vergunning aanvragen voor je evenement – een handig stappenplan. Opgehaald van eventbrite: <https://www.eventbrite.nl/blog/vergunning-aanvragen-evenement-ds00/>
- Forsyth, D. R. (2014). Group Dynamics. Belmont: Wadsworth Cengage Learning.
- Gebrek aan alertheid bij vergunning monster truck in Haaksbergen. (sd). Opgehaald van Onderzoeksraad voor veiligheid: <https://www.onderzoeksraad.nl/nl/page/6913/gebrek-aan-alertheid-bij-vergunning-monster-truck-in-haaksbergen>
- Groeneweg, J. (2020, May 4). Dordtse weekmarkt grotendeels goed verlopen: 'Maar sommigen zagen het toch als een uitje'. Opgehaald van AD: <https://www.ad.nl/dordrecht/dordtse-weekmarkt-grotendeels-goed-verlopen-maar-sommigen-zagen-het-toch-als-een-uitje~a0fe9eac0/>
- Hart van Zuid. (2020). Compleet vernieuwde busterminal Zuidplein. Opgeroepen op January 8, 2021, van <https://www.ahoy.nl/informatie/veelgestelde-vragen>
- Lieve, M. d. (2018, June 4). Bijna vier jaar na monstertruckdrama doet chauffeur zijn verhaal: "Kon ik het maar terugdraaien". Opgehaald van NH Nieuws: <https://www.nhnieuws.nl/nieuws/225741/bijna-vier-jaar-na-monstertruckdrama-doet-chauffeur-zijn-verhaal-kon-ik-het-maar-terugdraaien>
- Monster Truck Racing Association. (2014, January 1). Veiligheidseisen International Monster Truck Racing Association. Opgehaald van Instituut Fysieke Veiligheid: <https://www.ifv.nl/kennisplein/evenementenveiligheid/publicaties/veiligheidseisen-international-monster-truck-racing-association>
- NOS. (2014, September 30). Vergunning Haaksbergen "routine". Opgehaald van NOS: <https://nos.nl/artikel/704609-vergunning-haaksbergen-routine.html>
- NOS. (2015, February 17). 'Vergunning monstertruck ten onrechte verleend'. Opgehaald van NOS: <https://nos.nl/artikel/2019891-vergunning-monster-truck-ten-onrechte-verleend.html>
- Onderzoekcentrum Drechtsteden. (2020). Bevolking - Dordrecht. Opgehaald van Onderzoekcentrum Drechtsteden: https://ocd.buurtmonitor.nl/jive?cat_open_code=c1

- Onderzoekcentrum Drechtsteden. (2020). Monitor Coronacrisis. Sliedrecht: Onderzoekcentrum Drechtsteden.
- Onderzoeksraad voor Veiligheid. (2015, May 20). Gebrek aan alertheid bij vergunning monster truck in Haaksbergen. Opgehaald van Onderzoeksraad voor Veiligheid: <https://www.onderzoeksraad.nl/nl/page/6913/gebrek-aan-alertheid-bij-vergunning-monster-truck-in-haaksbergen>
- Oozoo. (2020). Wetenswaardigheden, cijfers en statistieken over Dordrecht. Opgehaald van Oozoo: <https://www.oozo.nl/cijfers/dordrecht>
- RET. (2019, February 22). Cijfers metro: Rotterdam Beurs is drukste metrostation van Nederland. Opgeroepen op January 8, 2021, van Treinreiziger: <https://www.treinreiziger.nl/cijfers-metro-rotterdam-beurs-is-drukste-metrostation-van-nederland/>
- RET. (2019). Jaarverslag 2019 RET. Opgeroepen op January 8, 2021, van <https://corporate.ret.nl/media/2899/jaarverslag-2019-ret.pdf>
- RTL Nieuws. (2014, September 28). Drama bij evenement Haaksbergen. Opgehaald van RTL Nieuws: <https://www.rtlnieuws.nl/nederland/artikel/1624806/drama-bij-evenement-haaksbergen>
- RTL Nieuws. (2015, October 28). Drama monstertruck Haaksbergen: vergunning gemeente onterecht. Opgehaald van RTL Nieuws: <https://www.rtlnieuws.nl/node/893851>
- RTV Oost. (2014, September 29). 'Verantwoordelijkheid voor ongeluk Haaksbergen ligt bij gemeente en organisatie' 1200 kbps geselecteerd als afspeelkwaliteit Veel hulpverleners in Haaksbergen (Foto: Erik Schaddelee) Veel hulpverleners in Haaksbergen (Foto: Erik Schaddelee) Syan S. Opgehaald van RTV Oost: <https://www.rtvooost.nl/nieuws/199444/Verantwoordelijkheid-voor-ongeluk-Haaksbergen-ligt-bij-gemeente-en-organisatie>
- Santayana, G. (1906). Reason in Common Sense.
- Schaap, S. (2015, June 10). GEMEENTEN MOETEN ÉÉN KADER GEBRUIKEN VOOR VEILIGE EVENEMENTEN. Opgehaald van Centrum voor criminaliteitspreventie en veiligheid: <https://ccv-secondant.nl/platform/article/gemeenten-moeten-een-kader-gebruiken-voor-veilige-evenementen>
- Schaap, S. (2020, September 10). Crowd Safety and Risk Analysis. Breda, The Netherlands.
- Spence, S. (2020, October 28). Right-wing extremism: The new wave of global terrorism. Opgehaald van World Economic Forum: <https://www.weforum.org/agenda/2020/10/right-wing-extremism-global-terrorism/>
- Statista. (2019, September). Number of festivals in the Netherlands from 2013 to 2018. Opgehaald van Statista: <https://www.statista.com/statistics/673435/number-of-festivals-in-the-netherlands/>
- Still, G. K. (2013). Introduction to Crowd Science. Boca Raton: CRC Press. Opgeroepen op oktober 14, 2020
- Still, K. G. (2019). Introduction to Crow Science. Boca Raton: Taylor & Francis Group.
- Still, K. G. (2019). Introduction to Crowd Science. Boca Rotan: Taylor & Francis Group.
- Still, K. G. (2019). Introduction to Crowd Science. Boca Raton: Taylor & Francis Group.
- Thalmann, D. (2016). Crowd Simulation. In N. Lee, Encyclopedia of Computer Graphics and Games (pp. 1–8). Springer International Publishing.
- van Driel. (2020, April 29). Markten in Zuid-Holland Zuid weer toegestaan, maar wel onder extra toezicht. Opgehaald van AD: <https://www.ad.nl/dordrecht/markten-in-zuid-holland-zuid-weer-toegestaan-maar-wel-onder-extra-toezicht~aa6efc74/>

- van Driel. (2020, April 30). Nieuwe regels tijdens de Dordtse weekmarkt: 'Houd afstand en blijf niet langer dan nodig'. Opgehaald van AD: <https://www.ad.nl/dordrecht/nieuwe-regels-tijdens-de-dordtse-weekmarkt-houd-afstand-en-blijf-niet-langer-dan-nodig~a5b28df5/>
- van Driel, I. (2020, April 29). Markten in Zuid-Holland Zuid weer toegestaan, maar wel onder extra toezicht. Opgehaald van AD: <https://www.ad.nl/dordrecht/markten-in-zuid-holland-zuid-weer-toegestaan-maar-wel-onder-extra-toezicht~aa6efc74/>
- van Driel, I. (2020, April 29). Markten in Zuid-Holland Zuid weer toegestaan, maar wel onder extra toezicht. Opgehaald van AD: <https://www.ad.nl/dordrecht/markten-in-zuid-holland-zuid-weer-toegestaan-maar-wel-onder-extra-toezicht~aa6efc74/>
- van Driel, I. (2020, April 30). Nieuwe regels tijdens de Dordtse weekmarkt: 'Houd afstand en blijf niet langer dan nodig'. Opgehaald van AD: <https://www.ad.nl/dordrecht/nieuwe-regels-tijdens-de-dordtse-weekmarkt-houd-afstand-en-blijf-niet-langer-dan-nodig~a5b28df5/>
- van Driel, I. (2020, April 30). Nieuwe regels tijdens de Dordtse weekmarkt: 'Houd afstand en blijf niet langer dan nodig'. Opgehaald van AD: <https://www.ad.nl/dordrecht/nieuwe-regels-tijdens-de-dordtse-weekmarkt-houd-afstand-en-blijf-niet-langer-dan-nodig~a5b28df5/>
- Vergunning Haaksbergen "routine". (2014, September 30). Opgehaald van NOS: <https://nos.nl/artikel/704609-vergunning-haaksbergen-routine.html>
- 'Vergunning monstertruck ten onrechte verleend'. (2015, February 17). Opgehaald van NOS: <https://nos.nl/artikel/2019891-vergunning-monstertruck-ten-onrechte-verleend.html>
- Vergunst, N. (2020, June 2). Crowd simulation software visualises layout for social distancing. Opgehaald van Utrecht University: <https://www.uu.nl/en/news/crowd-simulation-software-visualises-layout-for-social-distancing>
- Voerknecht, H., & van Bokhorst, M. (2018, March). Benchmark actieve, gezonde, duurzame mobiliteit gemeenten. Opgehaald van CE Delft: https://www.ce.nl/assets/upload/file/Rapporten/2018/4N74/CE_Delft_4N74_Benchmark_actieve_gezonde_duurzae_mobiliteit_gemeenten_DEF.pdf
- Vrie, K. d. (2020, June 21). TIP! – Welke vergunningen heb ik nodig om een evenement te organiseren?. Opgehaald van eventplanner: https://www.eventplanner.nl/nieuws/4569_tip-welke-vergunningen-heb-ik-nodig-om-een-evenement-te-organiseren.html
- Westland, E. (2020, March 13). Druk op de markt na maatregelen corona: 'Iedereen wil wat extra's te eten in huis hebben' Met name eieren zijn vandaag niet aan te slepen op de markt in Kanaleneiland. Foto: RTV Utrecht / Evie Westland Met name eieren zijn vandaag niet aan te slepen op de. Opgehaald van RTV Utrecht: <https://www.rtvutrecht.nl/nieuws/2027385/druk-op-de-markt-na-maatregelen-corona-iedereen-wil-wat-extras-te-eten-in-huis-hebben.html>
- Wijermans, F. E. (2011). Understanding crowd behaviour: simulating situated individual. Groningen: University of Groningen, SOM.

Willem van den Berge – the Rotterdamse Elektrische Tram (RET)

About Willem

Willem van den Berge is a traffic engineer from Rotterdam, the Netherlands. As part of his study programme, Willem has followed the minor “Crowd Safety in Hubs and Events”. During this minor, assignments were completed for multiple commissioners, such as municipalities and large event organisers. As part of the final assessment for the minor, a practical essay had to be written. In this essay, Willem chose to analyse a busy metro station in Rotterdam, and specifically when a large event is being held at the nearby venue.

Introduction

The Rotterdamse Elektrische Tram (RET) is the public transport operator for Rotterdam and the surrounding region. It ensures safe, comfortable and fast public transport by bus, tram, metro and even a Fast Ferry! The company is strongly connected with Rotterdam, operating public transport for almost 150 years.

In 2018, the RET transported over 174 million people, of which almost 100 million by metro. To transport all these people, RET has an extensive network of 5 metro lines, 10 tram lines and around 57 bus routes (RET, 2019).

The RET has, together with her partners, provided data and documents for this research, such as the event’s modal split, detailed information about procedures and several graphic plots with check-ins and check-outs at metro station Zuidplein.

Introduction Zuidplein

Opened in 1968, it is now one of the largest public transport hubs of the Netherlands. It takes second place in size and intensity, after Utrecht Centraal. Every day, around 40,000 passengers take the metro here, making it the third busiest metro station of Rotterdam (RET, 2019). The metro station is connected to the shopping mall Zuidplein and lies in close vicinity to the Ikazia hospital and event venue Ahoy.

Yearly, hundreds of concerts, fairs, congresses and meetings are held at Ahoy Rotterdam, making it one of the largest event venues in the Netherlands, offering an indoor capacity of around 16,000 visitors. This is not including the large outside areas (Ahoy Rotterdam).

Ahoy Rotterdam has a great accessibility by car, being located next to a large arterial road which leads straight to highway A15. Concerning public transport, Ahoy is connected via metro and bus station Zuidplein, offering direct connections up to Bergen op Zoom and Zierikzee. The metro takes the visitors to the central train station of Rotterdam and Den Haag, making public transport a great alternative (Hart van Zuid, 2020).

Introduction: The Flying Dutch

The Flying Dutch 2017 is the biggest outdoor dance festival of the Netherlands, offering a great line-up, such as Afrojack, Armin van Buuren, Bizzey and Tiësto. The event takes place at three different venues in the Netherlands, with DJ's flying back and forth with helicopters.

For the specific location at Ahoy Outdoor, the permit states a maximum visitor amount of 45,000 people. This number will probably be more towards 35,000. To maximise safety, 45,000 visitors will be used in the calculations.

The gates will open at 11 AM, with the event starting at 12 PM. The event ends at 11 PM. Because of the nature of the event, almost 50 percent of the visitors will come by public transport. The total modal split can be found in Table 32.

As can be seen in Table 59, around 20,000 visitors are expected to arrive via the network of the RET. To try and manage the extra visitor numbers on top of the regular passengers, RET has made the following arrangements back in 2017:

1. Instead of scaling down to single metro units during the evening, the RET will keep the double metro units in service during the whole day.
2. Between 11 PM and 01:30 AM, four extra metro units will be put into service between Zuidplein and Rotterdam Centraal, on top of the regular schedule.
3. Extra security and hospitality personnel will be deployed to ensure safety and crowd management, mainly at Zuidplein.

Research objective

The objective of this research is to perform a risk analysis regarding crowd safety at Zuidplein metro station. To further define this research, the focus will be on public transport, specifically the metro. This only includes the visitors for the Flying Dutch festival. At Zuidplein, only the main hall (level 1) will be analysed. This is also where the responsibility of RET starts.

Table 58 Modal Split of The Flying Dutch 2017

<i>Type of vehicle</i>	<i>%</i>	<i>Visitors</i>	<i>Vehicles</i>
Car	15%	6,750	2,411
Public Transport: Regional Bus	12%	5,400	N/A
Coaches	5%	2,250	41
Public Transport: RET	45%	20,250	N/A
Taxi, Kiss and Ride	8%	3,600	1,440
Bike, moped or walking	15%	6,750	N/A
	100%	45,000	3,892

RAMP

RAMP stands for Routes, Area, Movement and People/Profile. This model, proposed by Still (2013), comprehends the routes that the visitors use, the crowd density in various areas of the event site, the movement rates of the audience through various passages and the profile is the known and expected behaviour of the crowd.

In short, the RAMP model provides the different stakeholders and users with relationships between routes, areas, movement and the expected profile for the three phases (ingress, circulation and egress) for normal and emergency situations.

Routes

As this report focuses on public transport, only the routes to Zuidplein metro station will be discussed. The event venue is located very close to the metro and bus station Zuidplein; this will be the main route to and from the event venue. This can be seen in Figure 8. As the route crosses a busy road and conflicts with departing and arriving buses, traffic marshals and stewards have been put into place to ensure a safe crossing and a smooth traffic flow.

Overview of available routes to and from Zuidplein from Rotterdam Ahoy

After crossing the Zuiderparkweg, visitors are guided by stewards and Line-Up Gates to the stairs which led into the main hall. Around 95 percent of the visitors are expected to use the main route, which is referred to as route 1 in Figure 78. After 10 PM, the escalators at Zuidplein will be taken out of service by the RET.

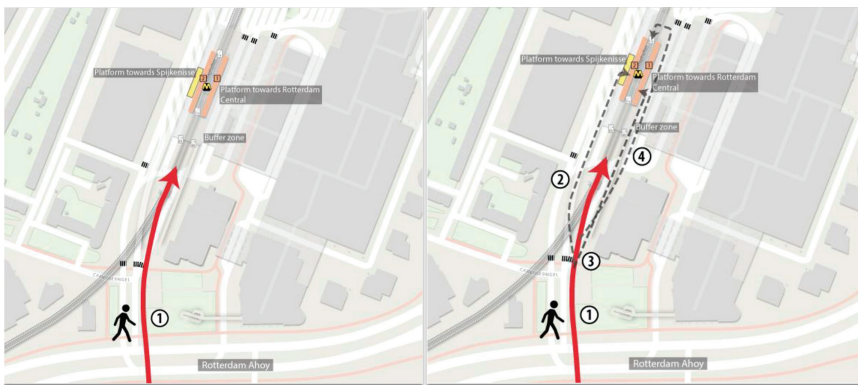


Figure 78 Overview of available routes to and from Zuidplein from Rotterdam Ahoy

Unfortunately, there are visitors who do not want to wait. They will try to walk up the ramp via route 2, which is bus-access only, take the pedestrian ramp via route 3, or walk around to the northern entrance of Zuidplein via route 4, and try to come in that way. Visitors will also try to take the elevators located at both ends of the platforms; these will also be taken out of service after 10 PM.

To prevent unwanted use of other routes, and to perform effective crowd control, stewards and security personnel are put into place to prevent people from using routes 2 and 3. When too many people use route 4, the gates to the main hall can be closed remotely by the RET. On the request of security or hospitality personnel, elevators can be put back into service for passengers who need the elevator.

As most of the visitors who come by public transport will use the same route (1), this becomes a high-risk route. Along the route from Ahoy to Zuidplein, toilets and garbage cans will be placed to prevent urinating in public and littering. Furthermore, Line-Up Gates help control the crowd flow onto the stairs leading up to the main hall. The crowd will also be regulated coming from Ahoy, as to not create a crowd build-up at the metro station.

Area

Metro station Zuidplein can be divided into three different zones, namely (see also Figure 10):

1. The square in front of the stairs at the southern part of Zuidplein
2. The main hall on level 1
3. The platforms 1 and 2 on level 2

Once the visitors have arrived at Zuidplein, they are first buffered on the square outside, as can be seen in Figure 79. After the metro has left, the next load of visitors is sent up towards the main hall and the platforms. Once the platforms are nearly full, passengers will be stopped and buffered again on the square in front of the stairs.

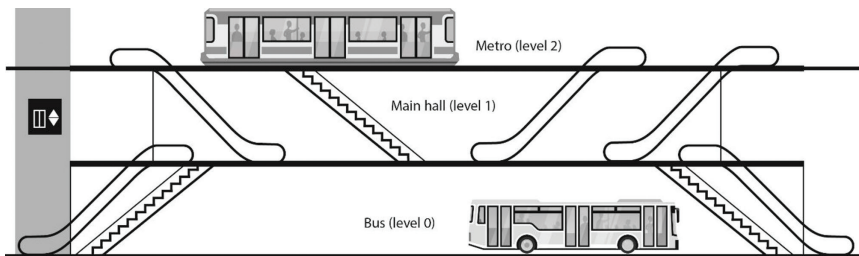


Figure 79 Side view metro station Zuidplein.

Below, the three zones will be discussed. For zone 2, a more detailed analysis will be conducted, as the research is focused on this part of the station. This includes the routes visitors take within the main hall.

Zone 1

This zone will be used to buffer visitors coming from Ahoy. With an average of two people per square metre, the capacity is around 1,300 visitors. This is around two full metros; this extra capacity provides safety and comfort for the passengers. However, on the square certain objects might lower the capacity, such as trash cans, billboards and other signage. Figure 80 shows a satellite picture, with the area of zone 1 as overlay. This is also the area where the Line-Up Gates will be placed.

Because the square is located outside, not very large risks exist. In the case of an emergency, visitors are free to go and can easily walk towards safety. If there is an emergency in Zuidplein itself, the visitors in zone 1 can also easily leave.

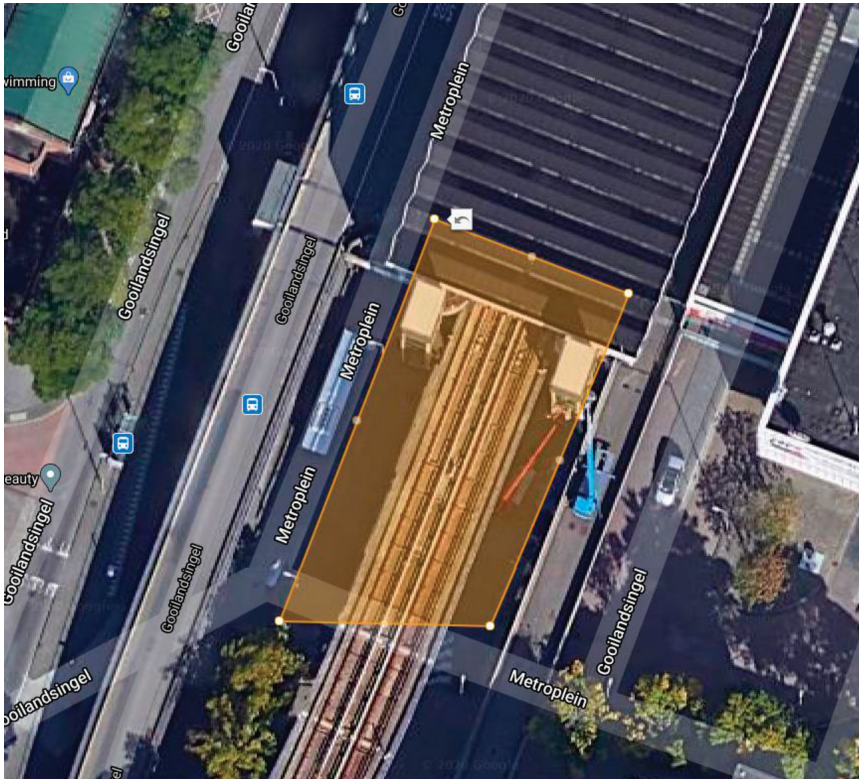


Figure 80 Area of zone 1

Zone 2

The main hall of the metro station is zone 2. In this area the passengers can choose in which direction they want to take the metro (Slinge/De Akkers or Rotterdam/Den Haag Centraal). Because zone 2 is located on level 1, it is also connected to the bus platform (which is only used for alighting) and the shopping mall Zuidplein.

As there are no (detailed drawings) available for this area, it is difficult to assess the exact capacity. After a site visit and experience, it becomes clear that the capacity of zone 2 largely exceeds the capacity of one metro. This allows for overflow and the occasional buffering of passengers.

This zone already poses more risks. In case of an emergency in shopping mall Zuidplein, lots of people can potentially come into the station and overcrowd it within a very short time period. Furthermore, this zone features the OV-Chipkaart gates, leading up to the platform. In the case a passenger does not have the right ticket, and this could cause a bottleneck. The presence of gates also slows down the flow rate during normal and emergency situations, although all the gates can be opened on site and remotely as well in the event of an emergency.

Figure 80 (left) shows the estimated crowd flow during ingress in the main hall of Zuidplein. For this mapping, three colours are being used. “Red” indicates that more than 80 percent of the visitors use this route, meaning that there is a high potential risk. The colour “Orange” indicates 50 to 80 percent of the visitors, and “Green” indicates less than 50 percent. These colours have been derived from Still (2013).

A lot of arrows near the southern exit are red, as the crowd adds up while leaving the station. Stairs and escalators form an obstacle and will very likely slow the flow of people down, as well as the OV-Chipkaart gates.

The flow rate of people is dependent on how much space they have. According to Still (2013), the flow rate is optimal at a crowd density of

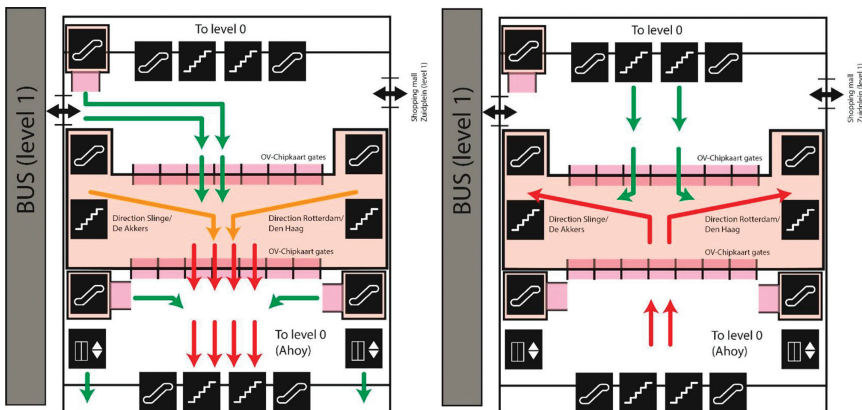


Figure 81 Routes in the main hall during peak 1 pm, 3 pm (left) and 11 am, 12 am (right)

around 2 to 3 people per square metre. With the stairs as obstacle, and looking at the parabola of Still, the stairs will slow down the flow rate to approximately 30 to 40 passengers per minute per metre. With an average width of about three metres, the stairs can process up to 160 people per minute.

For the OV-Chipkaart gates, a process time of 3 seconds per passenger has been assumed. This results in 20 passengers per minute per gate. At Zuidplein, at each entrance 7 gates are available. Again, assume that 4 gates are available for ingress. This results in 80 people per minute for the four gates.

As the flow rate of the stairs is larger than the flow rate of the gates, a queue will most likely form in front of the OV-Chipkaart gates.

During egress, some things change. This can be seen in Figure 80 (right). Below the stairs to level 0, the crowd of visitors will start to build up using the Line-Up gates. Visitors will be led the stairs in batches, as to not overcrowd the station. Escalators and lifts have been taken out of service, leaving only the stairs and fewer access points to the station and platforms. As can be seen, a lot of arrows are red. This is caused by the main route that the visitors take from the festival. Because of the active crowd management, this should not pose a risk. It just shows that it will become very busy.

Zone 3

This zone consists of the platforms 1 and 2 for the metro. Access is gained from the main hall via three stairs, three or four escalators and one elevator per platform. Each platform is around 120 metres long, based on the length of the metro, with a varying width.

Again, no (detailed) drawings which are publicly accessible exist on the platforms. It is assumed that the capacity of the platforms is larger than the maximum capacity per metro. Figure 82 shows a basic sketch of the two platforms.

With a very crowded platform, several risks can occur. People are limited in their movement and where they can go, but most importantly, passengers can fall onto the train tracks. This cannot only cause harm to the person who fell. It also means that the metro traffic has to be stopped for a certain period of time. With, in the worst case, 20,000 visitors who want to catch their last connection to get home, this can cause panic and aggression.

Movement

The expected peak of incoming visitors will be between 1 PM and 3 PM. For the departure of visitors, a peak is expected directly after the festival, with around 35 percent of the visitors leaving. The organisers have chosen to let a head liner (Afrojack) close the festival, meaning that most of the visitors will want to stay until the end.

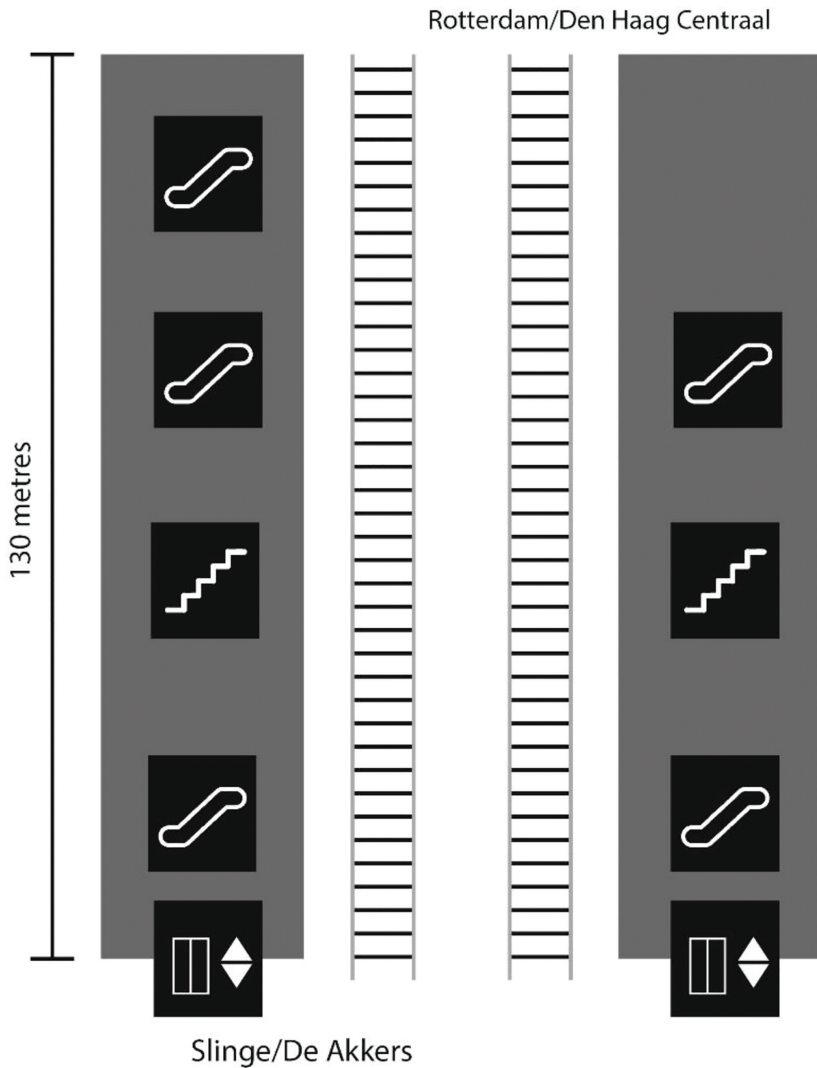


Figure 82 Sketch metro station Zuidplein

Ingress

The expected ingress for the Flying Dutch is based on previous editions and other festival experiences. Between 1 PM and 3 PM, around 10,000 visitors will arrive via the network of the RET. Figure 83 shows the distribution of visitors during ingress between 10 AM and 6 PM. This will cause extra crowdedness in the metro carriages and at Zuidplein on the stairs and at the OV-Chipkaart gates.

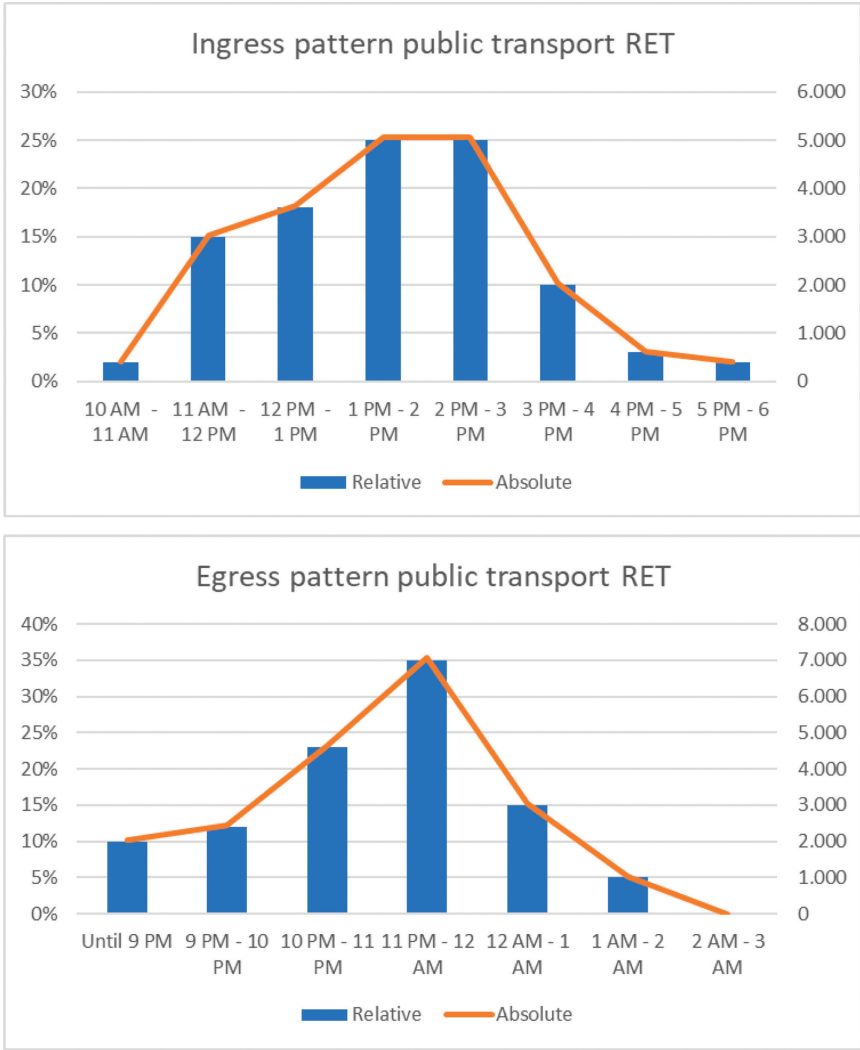


Figure 83 Ingress/egress pattern public transport RET

Egress

Most visitors will start leaving around 9 PM, with a real peak between 11 PM and 12 AM. This makes sense, as the festival ends at 11 PM. After 1 AM the flow of people who take public transport quickly decreases, as most public transport lines do not run after 12 AM/1 AM. Figure 83 shows the egress pattern for the network of RET.

On regular weekdays, event visitors make use of the public transport. This is on top of the regular passengers. To illustrate the extra number of

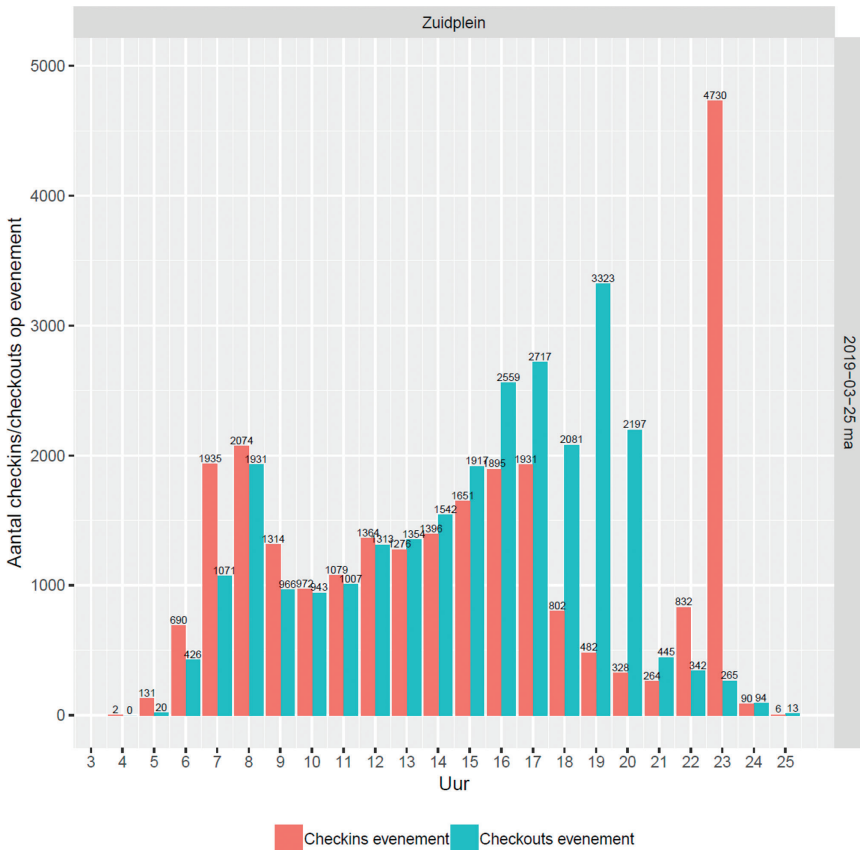


Figure 84 Florence and the Machine at Zuidplein metro (RET, 2019)

passengers the metro system has to process (Figure 84). It shows the check-ins and check-outs at the metro station Zuidplein during a concert of Florence and the Machine on the 25th of March 2019. Unfortunately, such plot is not available for the Flying Dutch 2017 but still serves as a great example.

Looking at the morning rush hour, one can see a peak of around 2,100 check-ins between 7 and 8 AM. After Florence and the Machine have finished playing, a peak of almost 4,800 check-ins can be witnessed, doubling the number of passengers during morning rush hour.

For the Flying Dutch, a same peak can be expected, but even more extreme. Within one hour, more than 7,000 people will try to take the metro. This makes good crowd management extremely important, as the metro system can process around 6,480 passengers per hour, based on two metro trains (RSG3), with a combined capacity of 540 places and a 5-minute headway.

Profile

The Flying Dutch Rotterdam 2017 is a dance festival, with an expected visitor number of 35,000. The cultural background of the Flying Dutch is diverse, and the female-male ratio is almost equal, with around 55 percent female visitors.

The target group ranges from the age of 18 to 36 years and is an experienced festival visitor, both indoor and outdoor dance events. This can be seen in Figure 85. Based on previous editions, one could conclude that the event has a regional coverage. One of the main characteristics of a dance event is that visitors will dance very intensely for prolonged periods of time. The organisation does not expect any rival groups attending the festival, or any weaker visitor groups, such as parents with children, elderly or disabled people.

Because this is an 18+ event, the organisation is allowed to serve alcohol. This could potentially change the behaviour of the visitors after having one too many beers. Furthermore, the organisation has a “zero tolerance” policy for drug use. This does not mean that no drugs will be used.

DIM-ICE

The DIM-ICE model is used to analyse the risks that correspond with the Design, Information and Management of an event. These are the three

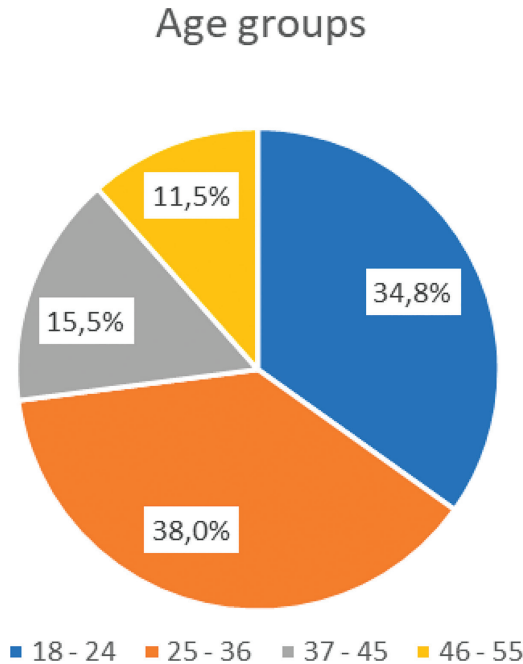


Figure 85 Distribution of age between visitors.

main influences on crowd behaviour. This is further divided into the three main phases of an event, namely, Ingress, Circulation and Egress.

Each of those phases has a different influence on the visitor and his or her behaviour. Colour-coding can be added to assess the level of risk (high, medium or normal). This also shows the user a clear overview of points to improve. Furthermore, the model consists of two situations, namely, the normal and emergency situation. For this research, only zone 2 (Main Hall, level 1) will be analysed during the Flying Dutch 2017 (Table 60-61).

Normal situation

Table 59 DIM-ICE Normal

Zone 2 (Main Hall, level 1)	Ingress	Circulation	Egress
Design	Station is designed for large numbers of passengers, but bottle necks can occur at escalators, stairs and OV-Chipkaart gates. Access points to and from the platforms are distributed. But all the visitors will tend to leave through the same exit (south), conflicting with regular passengers.	No ingress or egress of the Flying Dutch, capacity of metro station is more than sufficient for regular passengers.	Regular passenger numbers are low, leaving more capacity for visitors. Bottle necks can occur at the stairs and OV-Chipkaart gates. Line-up Gates are being used below the main stairs (level 0) to ensure a smooth flow of people.
Information	Very limited signage, but Rotterdam Ahoy is visible from the metro station. Announcement system is in place, as well as digital signs.	Departure times are listed at each entrance, as well as the departure times of the buses.	Very limited signage, but Zuidplein is visible from Ahoy. Announcement system is in place, as well as digital signs.
Management	Four extra security and two hospitality staff members are being deployed to help and manage the extra flow of passengers at Zuidplein. Bikes are not allowed during the day in the metro to keep as much space free as possible.	Four extra security and two hospitality staff members are being deployed to help and manage the extra flow of passengers at Zuidplein.	Seventeen extra security and two extra hospitality staff members are being deployed to help and manage the extra flow of passengers at Zuidplein. Security personnel is responsible for departure of extra metros from Zuidplein.

Table 60 DIM-ICE Emergency

Zone 2 (Main Hall, level 1)	Ingress	Circulation	Egress
Design	Exits to shopping mall and bus platform (level 1). OV-Chipkaart gates will open, leaving free access to large stairs leading to level 0.	Exits to shopping mall and bus platform (level 1). OV-Chipkaart gates will open, leaving free access to large stairs leading to level 0. No extra visitors of Flying Dutch, so plenty of capacity.	Exits to bus platform (level 1) and main stairs leading to level 0. Station will be filled with visitors, also on platform, making those visitors 'invisible'. Stairs to level 0 on south side will be partially blocked by waiting visitors.
Information	Limited signs showing emergency exits, but there are SOS-poles to open the gates and to call for help. Announcement system is in place, as well as digital signs.	Limited signs showing emergency exits, but there are SOS-poles to open the gates and to call for help. Announcement system is in place, as well as digital signs.	Limited signs showing emergency exits, but there are SOS-poles to open the gates and to call for help. Announcement system is in place, as well as digital signs.
Management	Four extra security and two hospitality staff members can assist in evacuation or another emergency. Bikes are not allowed during the day, so less obstacles to worry about.	Four extra security and two hospitality staff members are being deployed to help and manage the extra flow of passengers at Zuidplein.	Seventeen extra security and two extra hospitality staff members can assist in evacuation or another emergency. Traffic control can shut down metro traffic and open all the OV-Chipkaart gates.

As can be seen, there are no big risks during a normal situation. The amber coloured parts are mostly related to design and can be hard to solve within an existing station. However, it is important to keep these factors in mind. It is surprising that during ingress, there is no real crowd management at Zuidplein, even though the passenger numbers are quite high (5.000 per hour). Also, no extra metros are being scheduled.

Emergency situation

During an emergency situation, more amber and even red appear in the matrix. This is, again, mainly caused by design issues. During egress, the exit to the shopping mall is closed, leaving only the bus platform and the two main entrances available. Furthermore, there are very limited emergency exit signs present at Zuidplein.

When the station is full of visitors and it has to be evacuated, there will be some issues. Passengers stuck on the platform (level 2) must go through the main hall (level 1) to go outside safely. If the main hall is blocked or still filled with other passengers, they will be trapped on level 2, as there are no other exits.

The extra security and hospitality personnel will provide a good and concise evacuation and can assist in other forms of emergencies. The traffic control also has dozens of cameras at Zuidplein to keep a good eye and help out wherever necessary.

Risk mapping

By using the tool “Risk Mapping” in combination with the RAMP and DIM-ICE analysis, one can analyse and “map” the different risks and congestion than can occur at the metro station Zuidplein. Below, two maps have been made: one for the ingress and one for the egress.

Ingress

During ingress, most congestion will occur on the stairs leading within the “Check-in zone”, as these access points are in the middle of the platform. The other two exits are located more towards the front and rear end of the metro. Furthermore, it is very likely that there will be queueing at the OV-Chipkaart gates, as scanning a card and waiting for the gates to open takes time. At the large stairs leading to level 0 at the Ahoy-side, only light congestion can be expected. The OV-Chipkaart gates slowed it down already, leaving “clean” space after the gates.

Egress

After the festival, during egress, most congestion will occur outside the metro station. This is done on purpose, as the risks are lower in an outdoor environment. The biggest risk for crowd congestion is within the “Check-in zone”, as it is very likely that crowd flows will conflict with each other. This will slow down the flow rate even more. Also, in the case a passenger does not have enough money, the gates will not open, and this will cause a hold up, slowing down the flow rate. The northern entrance is also marked “Yellow”, as it is not preferred that this entrance is used. The elevators and escalators have not been mapped for egress, as they will be taken out of service in time.

Decision support analysis

A decision support analysis can be used to map one set of variables against another. For Zuidplein, this could be the state of the metro network for example. This could then be mapped against the different zones or locations within a zone, such as stairs, elevators, OV-Chipkaart gates, vending

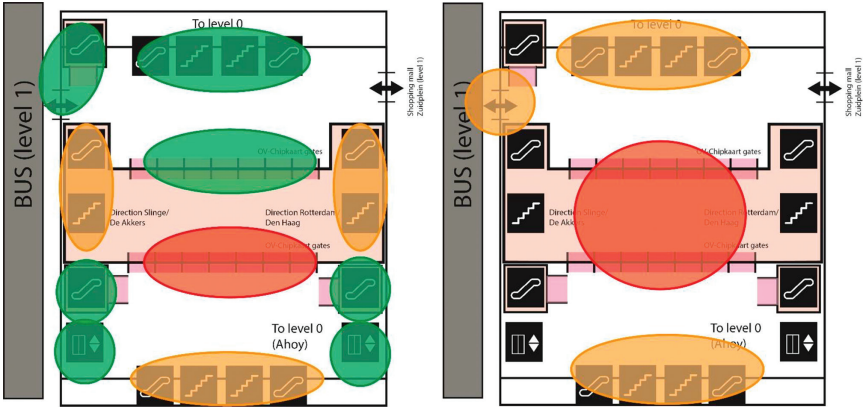


Figure 86 Risk/congestion for Ingress/Egress

machines, etc. For this matrix, three levels of service disruption will be used, which can be found. These levels of disruption will be mapped against different locations in the main hall, as can be seen in Table 62-63.

During a minor disruption, most passengers will stay put on the platforms and wait for the metro to come. That is why the impact is (very) low. During a severe disruption, crowds can build up at the OV-Chipkaart gates and at the access points to the platform. Because the metros are still running, this has been labelled as “High impact”.

When there is no service, all the passengers will want to leave the station. That is why the OV-Chipkaart gates and Access points platform have been marked as “High impact with risk”. The stairs have been coded “High impact”, as everyone will use these to get out of the station and there is more space available than at the gates.

Conclusion

To conclude this report, the main focus areas are within the “Check-in zone” on level 1. This is where most conflicting passenger flows can occur and will happen. This could be solved by using the northern entrance of Zuidplein as well.

Table 61 Risk Definitions

Minor disruption	Some metros are running with a minor delay, but overall traffic is good. For example, a metro got held up at a station because of the crowdedness.
Severe disruption	Limited traffic on the network, caused for example by a broken-down metro, passengers on the tracks or infrastructural problems.
No service	No metros are running from Zuidplein.

Table 62 Decision Support Analysis. Congestion Risk Assessment

<i>Model for potential congestion at Zuidplein Station</i>						
	OV-Chipkaart Gates	Vending Machines	South Stairs	North Stairs	Elevators	Access points platform
Minor Disruption						
Severe Disruption						
No Service						

High Impact with risk	
High impact	
Medium impact	
Low impact	

This will allow for a more spread-out passenger flow. However, this possibly requires more preparation regarding gates and fencing, as well as personnel.

Additionally, crowd management should be applied during ingress, as the passenger numbers strongly exceed the normal rush hour passenger numbers.

Furthermore, it is strongly advised to not use zone 2 on level 1 as a buffer zone, but to let the passengers go directly from zone 1 on level 0 to the platforms on level 2. This also makes a possible evacuation from the platforms easier and allows for more “breathing” during the whole crowd management process. Possibly, it can be wise to make a back-up plan, in case of a “No service”-scenario. This could be done in the form of RET buses or agreements with other bus companies, to provide shuttle services.

**Roderick van Gelder – Cold Chisel
at Parramatta (Australia)***About Roderick*

Roderick van Gelder has been working as a Risk Assessor and Safety Consultant for the entertainment industry since 2002.

A qualified Risk Manager, Roderick combines that knowledge with 25 years of experience as lighting designer and production manager for many national and international touring arts organisations to provide risk management solutions with an in-depth understanding of the entertainment industry. His career has taken him throughout Europe and the United States working with a long list of theatre, dance and opera companies in many capacities from production manager and technical director to stage manager and lighting designer. In a major career move in 1990 he accepted a residency as production manager and lighting designer for Sydney Dance Company where he lit many productions. From 1993 he continued to design productions throughout Australia and Asia. He was Technical Manager for Baryshnikov's Australian and New Zealand 1996 tour and the opera Aida in Singapore in the same year.

After accepting the position of Technical Manager at the Hordern Pavilion and Royal Hall of Industries in 1998, Roderick became interested in risk management and occupational health and safety for the entertainment industry. In 2004 he started Stage Safety, a small company providing services to the entertainment industry and corporate events. In that capacity Roderick has been involved in a many facets from corporate events for Qantas, Telstra, Lexus, Toyota, IBM, Woolworths, Nissan, Myer, Virgin Atlantic, MBF, Harley-Davidson, Sony to name but a few, to the arts for Opera Australia, Sydney Symphony Orchestra, Glen Street Theatre, to concerts and festivals such as V-Festival Australia, Jack Johnson, Jamiroquai, Daft Punk, Sydney Comedy Festival to celebrations such as the Sydney Harbour Bridge 75th Birthday for the NSW Premiers Department and the 2008 New Years' Eve celebrations for the City of Sydney. His passion for an analytical and mathematical approach to risk management fitted like a glove for the Crowd Science training he received from Prof. Keith Still.

Roderick has been providing targeted OH&S and risk management training for entertainment professionals. Roderick has been invited to present at various conferences such as the Venue Management Association (Australia), PALME in Singapore and LETPC in Johannesburg.

Frustrated by the lack of clear information about health and safety for the entertainment industry in Australia, Roderick ran a successful crowd-funding campaign in 2016 to start the Australian Entertainment Safety Resource Guide. It follows in the footsteps of the UK Purple

Guide and the USA Event Safety Guide. A series of seminars around Australia in all major cities provided much feedback from the industry and the regulators. The Australian Entertainment Safety Resource Guide aims to be the industry 'best practice' reference source.

Case Study – Cold Chisel

This report reviews a possible concert by the legendary band Cold Chisel at a newly created venue in Parramatta Park. The area is a natural amphitheatre that recently had a hardstand added so that it can be used of community events and concerts. It also had power distribution installed around the edge of the site and some other services for event use.

The city of Parramatta is approximately 25 kilometres west of the Sydney CBD. Parramatta is easily accessible from the CBD by train, bus or ferry. The concert site is located inside Parramatta Park which itself is in the heart of Parramatta. There are two train stations (on the same line) within 1 kilometre from the site. There are only 2 gates that allow vehicular access and an additional 4 gates that allow for pedestrian access.

The band

Cold Chisel is a rock band that originated in Adelaide, Australia, in 1970s. Cold Chisel is regarded as having a distinctly Australian popularity and musicianship, exemplifying "pub rock" and highlighting the working-class life in Australia. The band¹⁹ broke up in 1983 but reunited in 1998 and has since been performing intermittently.

Demographics

The band has a strong fan base, predominantly male blue collar workers, but with a wide following across the population. Many people who grew up with Cold Chisel are still strong supporters of the band and often take their teenage children to concerts. This creates a diverse audience across several generations.

Modes of transport

Within the demographics of the Cold Chisel fan base the car is the preferred form of transport. It is expected that 60% of the audience will arrive by car with the remaining 40% split evenly between public transport (bus/train) and foot traffic. Note that some of the foot traffic may be people who initially arrived by car but parked outside Parramatta Park. For the sake of on-site logistics only actual cars inside the park are shown.

¹⁹ Wikipedia:http://en.wikipedia.org/wiki/Cold_Chisel

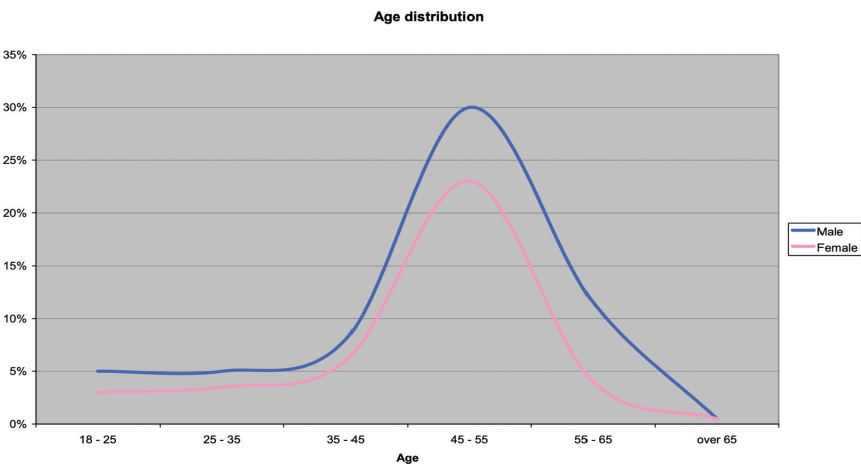


Figure 87 Cold Chisel, Fan Demographics

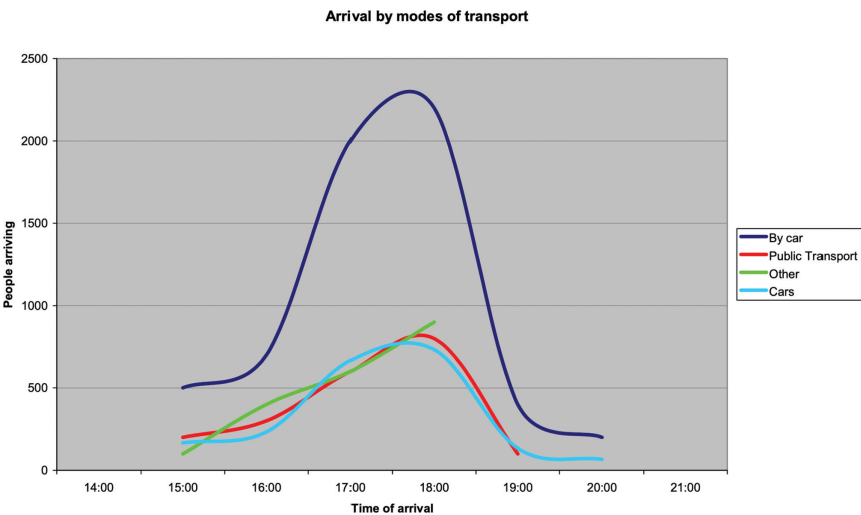


Figure 88 Modal split

People arriving are shown in dark blue, the cars they arrive in are shown in light blue. The calculation is based on an average of 3 pax/car.

Arrivals on site

Figure 89 shows how the crowds will enter Parramatta Park and then the concert site.

Pedestrians will enter primarily through the O’Connell Street gate. Some pedestrians coming from the station are more likely to arrive through Pitt

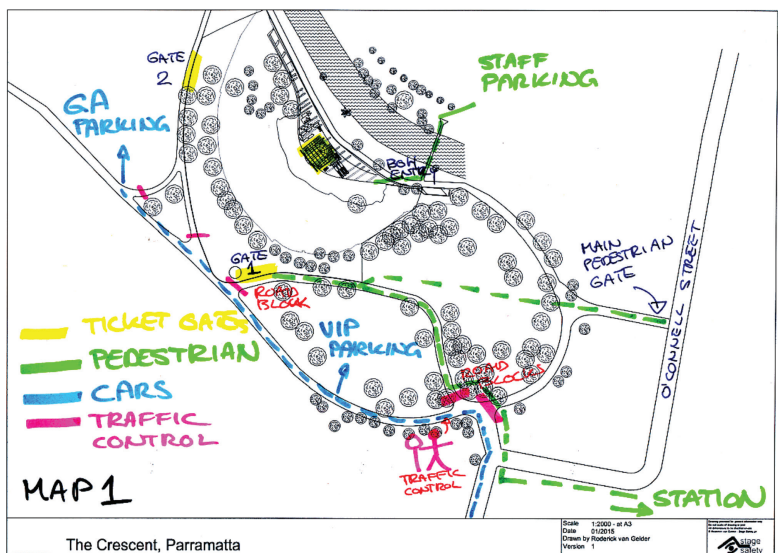


Figure 89 Map 1

Street gate. Roadblocks and traffic controllers will separate cars from pedestrians and stop traffic when necessary for pedestrians to pass safely.

Cars will all enter from Pitt Street and then proceed towards the VIP and GA parking areas. VMS and parking attendants will manage the flow of cars to the correct parking area for their ticket.

Crew and staff will utilise the Parramatta Stadium car park and enter the site via the pedestrian bridge and enter through the BOH Gate.

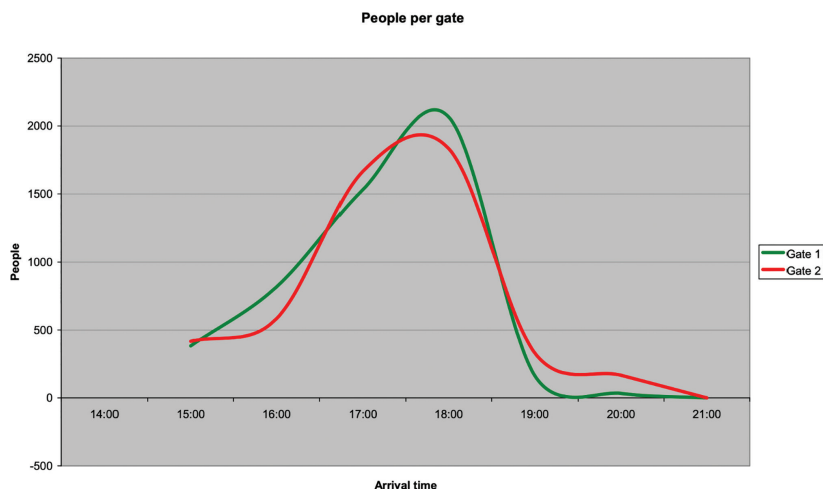


Figure 90 Arrivals/departures

The concert

The venue is an outdoor venue. The Park is open all day but the gates to the event site will open from 15:00 (3PM) to allow for a smooth filling of the space. There will be a DJ on stage from 16:00–17:00 and a support act (TBD) from 17:30 to 18:30. Cold Chisel will go on stage at 19:30 and finish at 22:30.

Access to the concert site

There will be two blocks of ticket entry gates, both at the back of the concert site. Gate 1 will service people arriving by foot, including all public transport arrivals, and a VIP parking entrance. Gate 2 will service all GA parking arrivals. The expectation is that 1000 VIP tickets will be sold. VIP Ticket holders usually arrive later than GA tickets because they know their area is reserved and they do not have the urge to arrive early for a better position. The expected peak time for ticket entries is between 17:00 and 19:00. Both gates will need to process just over 30 pax/minute at the peak between 18:00 and 19:00.

The demographics of Cold Chisel fans indicates that bag checks for alcohol will be required for anyone with a large bag. That will slow down the flow rate to an estimated 6 px/gate/minute.

Based on a balanced calculation between arrivals, service, and cost and accepting that some queuing may occur at brief moments during the peak, Gate 1 will have 4 ticket check/bag check gates and 1 VIP ticket check/bag check gate and Gate 2 will have just 4 ticket check/bag check gates.

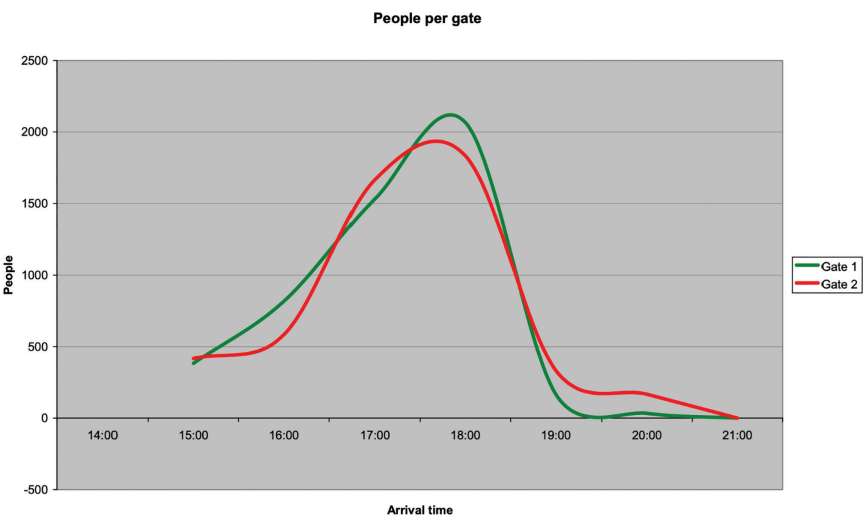


Figure 91 Arrival time at gates

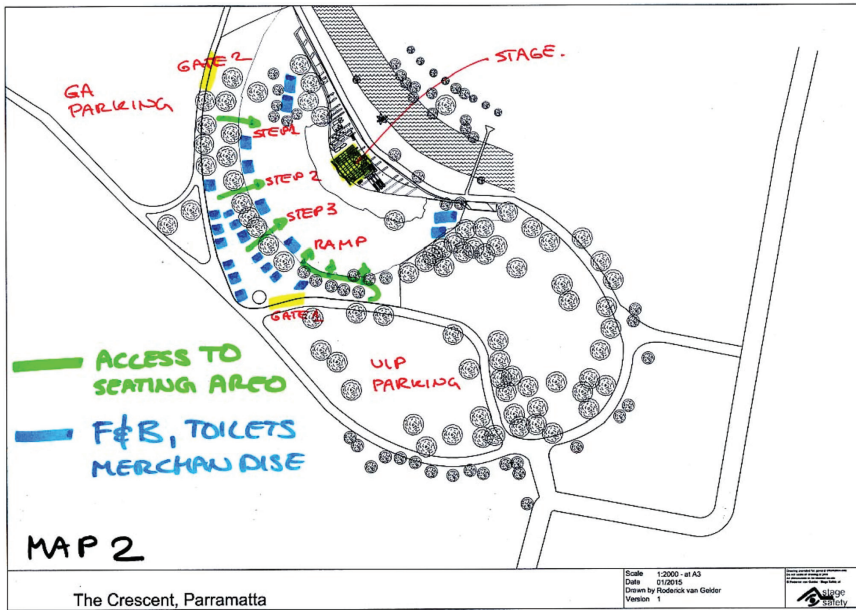


Figure 92 Map 2

Circulation

Both sets of gates are at the top of the natural amphitheatre. There is a large area in between trees that provide shade where food and beverage outlets will be set up as well as merchandise and some of the toilet blocks. Between the service area and the concert area are rows of trees that obscure the view from that area. From this service area there are 3 sets of steps, each 1.6 metres wide and a 3-metre-wide ramp that leads to the top of the amphitheatre which is approximately 3 metres lower than the service area. There are two sets of steps that lead from midway of the ramp to the top of the amphitheatre.

The aggregate width of egress is 8 metres which, based on a conservative 60person/metre/minute because of the steps, allows for 480 people to enter the concert area per minute. This would allow to space to fill with the expected 10,000 people in about 21 minutes, but that is only theoretical. As we saw in Fig. 4 arrivals will be spread out over 4 hours.

Even at peak times at the gates those arrivals are substantially less than the ingress capacity of the area from the service area. Even if we would half the capacity to allow for a contra-flow of people going from the concert area to the service area there is still enough width available for a comfortable flow of people.

The amphitheatre has a slope of approximately 8 degrees from horizontal (8 metres over 55 metres).

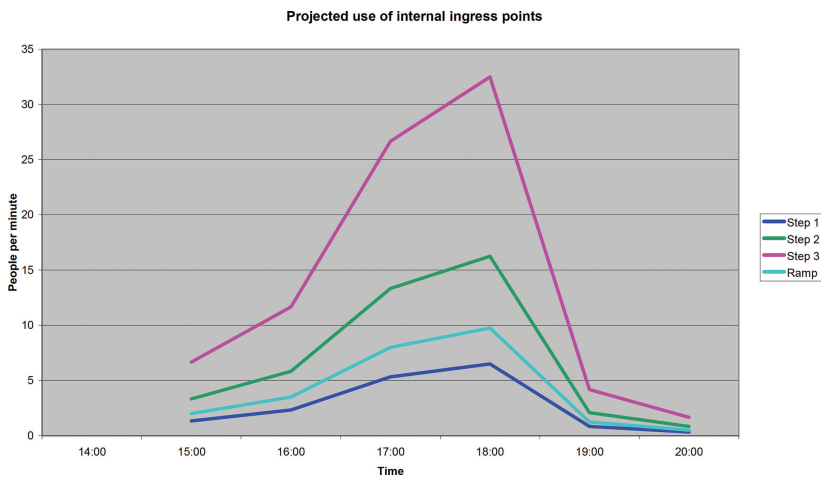


Figure 93 Projected internal gate usage

Egress

For egress under normal circumstances the same 4 points will be used. Because of the stairs there is expectancy that the less challenging ramp may be favoured over the available stairs.

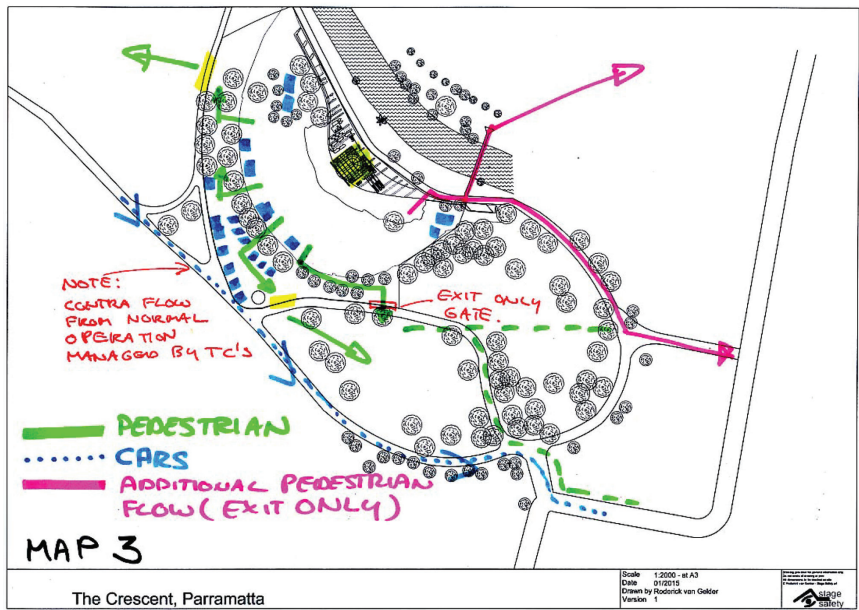


Figure 94 Map 3

The graph below will show that although we have a capacity to clear the venue at a rate of 400 pax per minute, Step 1 and Step 2 will be under-utilised and the Ramp and Step 3 will be over-utilised causing backlogs and queuing.

The graph shows that with an even distribution of 50 ppm over the 4 exit points the park could clear at 400 pax/minute and have everyone outside in 25 minutes. When we then take into consideration that Step 1 and Step 2 will be under-utilised, and Step 3 and the Ramp will be overcrowded we will see a build-up of waiting people at a calculated rate of 80 pax/minute.

It is only when no more people are leaving that the queue starts reducing and the park will be clear in 30 minutes.

There is the potential to create an additional egress point at SL of the main stage for use by pedestrians only who do not require to go to the car parking area. This would include people who arrived by foot and public transport.

That option could be attractive to 75% of the expected 4000 pax arriving by foot. The crowds could disperse across the pedestrian bridge leading

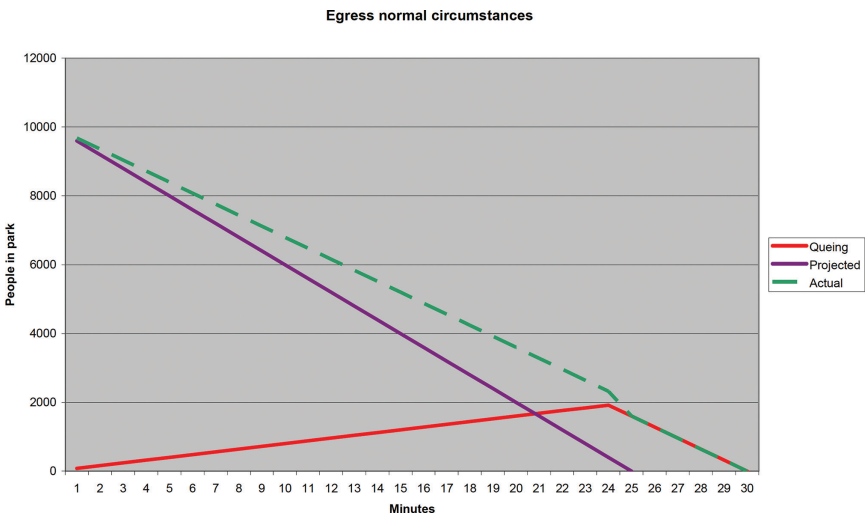


Figure 95 Normal egress

Table 63 Flow rates

	Step 1	Step 2	Step 3	Ramp
Width	1.6m	1.6m	1.6m	3.2m
Capacity (Width x 50ppm)	80ppm	80ppm	80ppm	160ppm
Projected use	10%	10%	30%	50%
Actual use	40ppm	40ppm	120ppm	200ppm
Over/under	-40ppm	-40ppm	+40ppm	+40ppm

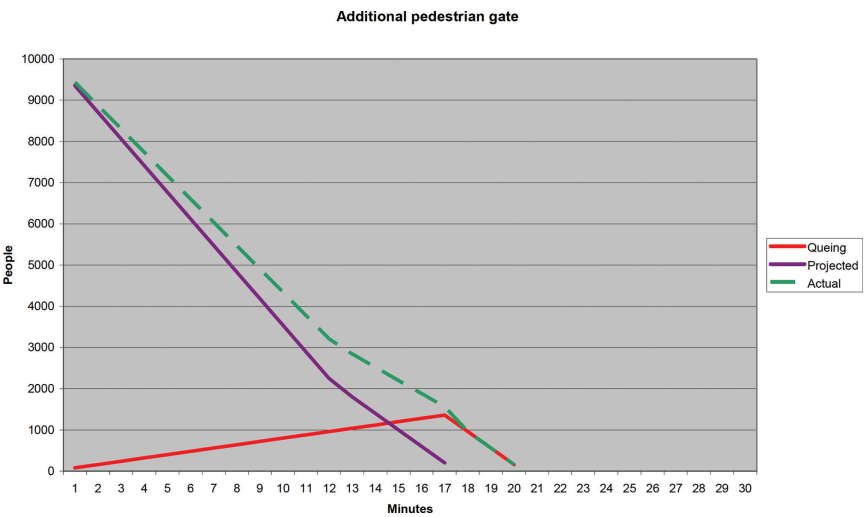


Figure 96 Additional pedestrian gates

to the Parramatta Stadium area and car park and through the pedestrian gate to O’Connell Street. That would reduce the number of people leaving through the top by 3000 pax. The effects of an additional gate with a capacity of 200pmm are shown in this graph.

Emergencies

And finally, we need to look at an emergency evacuation of the site. One of the key factors in an emergency evacuation is to separate the evacuating people from the arriving Emergency Services as good as possible. All Emergency Services will arrive through the Pitt Street vehicular entrance point and then take either or both routes as shown in Figure 96. To keep people clear from these areas both the Ramp and the SL pedestrian gate will be kept out of action but an additional exit gate at SR can be utilised. The bonus is that this gate is at the bottom of the slope and will allow for a much faster evacuation at 82 pmm.

Based on this calculation, it will take 16 minutes to completely clear the concert area. Security staff will be deployed to guide people to the available exits and to keep the SL Gate and Ramp clear for Emergency Services.

In this projection, 6400 people will leave through the exit gates at the bottom of the amphitheatre and 3600 people will leave though the 3 sets of steps at the top of the amphitheatre.

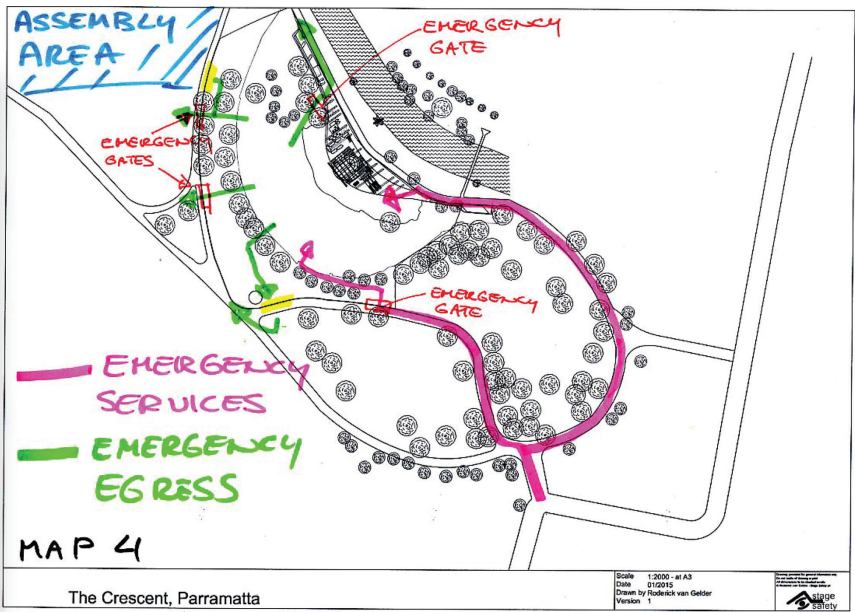


Figure 97 Map 4

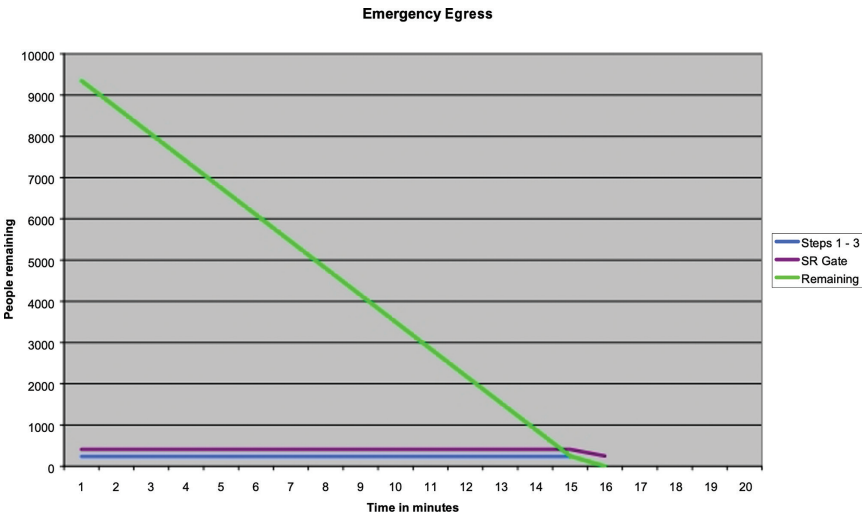


Figure 98 Emergency Egress

Crowd movement

Table 64 DIM-ICE (Crowd movement)

<i>Normal</i>	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Design	Provide sufficient gates for number of tickets sold.	Maintain sufficient clear areas for people to move around	Provide additional egress points to improve egress flows
Information	Clear site signage, provide details with ticket information	Clear signage, well-lit circulation areas	Utilise LED screens to indicate additional exit gates
Management	Sufficient staff to manage all essential locations efficiently	Safety marshals to monitor all areas and keep thoroughfares clear	Sufficient staff to manage all essential locations efficiently
<i>Emergency</i>	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Design	All infrastructure to be easily removed to improve flows	Keep sufficient width between infrastructure to allow unimpeded flows	Provide additional 'break-out' gates to be used in emergencies only.
Information	Loud hailers and PA systems to be used to communicate with the crowd	Loud hailers and PA systems to be used to communicate with the crowd	Utilise LED screens to indicate additional exit gates
Management	All staff to be trained in emergency procedures and codes	All staff to be trained in emergency procedures and codes	All staff to be trained in emergency procedures and codes

Traffic Management

Table 65 DIM-ICE (Traffic Management)

<i>Normal</i>	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Design	Separate cars and pedestrians as much as possible.	Roadblocks to prevent cars entering pedestrian areas.	Separate cars and pedestrians as much as possible.
Information	Provide traffic, both car and pedestrian, information with ticket information. Clear signage	Clear signage (VMS) to direct traffic to the correct area	Utilise LED screens to explain egress traffic management
Management	Deploy Traffic Controllers to manage cars entering the park	Parking attendants to manage parking areas	Deploy Traffic Controllers to manage cars leaving the park
<i>Emergency</i>	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Design	Maintain access for emergency vehicles at all times	Allow easy access for emergency vehicles to all areas	Always maintain access for emergency vehicles
Information	VMS to advise crowd of changed conditions	PA / Loudhailers to address crowd	PA / Loudhailers to address crowd
Management	All TC's to be trained in emergency systems	All attendants to be trained in emergency systems	All TC's to be trained in emergency systems

Food and Beverage

Table 66 DIM-ICE (Food and Beverage)

<i>Normal</i>	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Design	Bags checked for alcohol being brought onto site which could be a breach of licensing conditions	F&B areas clearly visible from entrance but not impeding on crowd flows. Designated queuing areas to maintain crowd flows throughout the site	N/A
Information	Clear signage to explain that alcohol may not be brought onto the site.	Provide clear signage to F&B areas. Clear signage about products and services provided	Clear indication when F&B outlets will close
Management	Provide “amnesty bins” for alcohol. Bag checks for hidden alcohol.	All F&B areas clearly identified and managed by F&B manager. Over 18’s only, no need for “proof of age”.	Close all F&B outlets prior to concert finishing to minimise “hangers-on”.
Emergency	Ingress	Circulation	Egress
Design	Ensure F&B infrastructure does not impeded on egress	Ensure F&B infrastructure does not impeded on egress	Ensure F&B infrastructure does not impeded on egress
Information	All F&B outlets to be provided with 2-way radios to always maintain contact with the F&B manager	Ensure all required signage as specified in the licensing conditions is displayed	N/A
Management	F&B Manager to monitor crowd flows and adjust F&B where necessary	Close all F&B areas in case of an emergency	Close all F&B areas in case of an emergency

Risk maps

4 risk maps were created for the event covering the following time slots:

Gates (15:00) – 18:00 = Quiet period

18:00–19:30 = Peak period

19:30 – 22:30 = Main act on stage

22:30 – 24:00 = Egress after the concert.

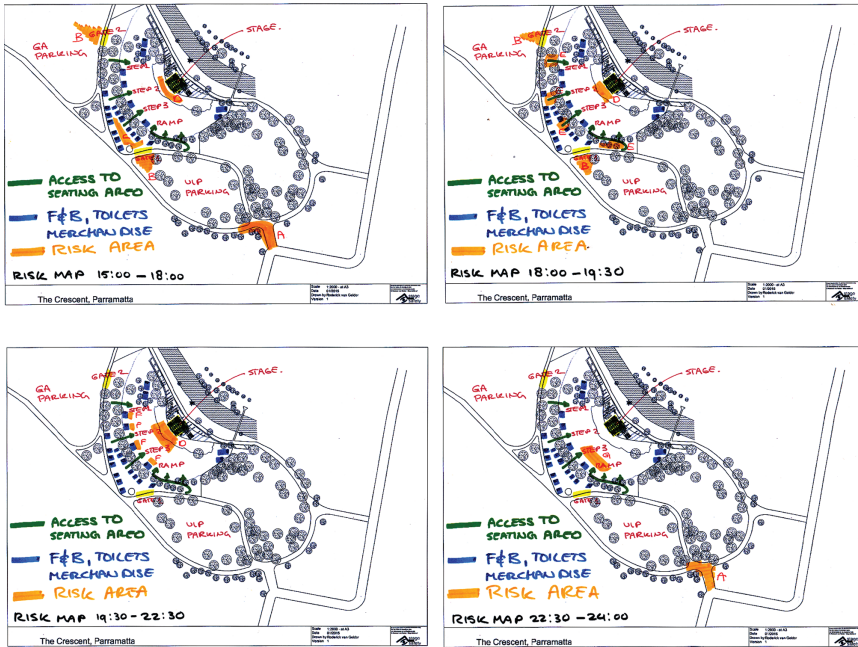


Figure 99 Site risk maps

The areas are marked as follows:

- Traffic risk. This is one area where cars and pedestrians may mix. It will be controlled and managed by experienced Traffic Controllers with instruction to stop cars when groups of pedestrians need to pass. However, those stops must be brief not to cause a traffic jam onto Pitt Road.
- Queuing at the ticket gates. Minor risk, only expected at peak times, but may occur at other times. Staff to monitor the situation and advice crowd control if crowds start building up.
- Overcrowding of the F&B and Merchandise areas. Safety marshals to monitor, direct people to other F&B areas and remain in contact with crowd control.

- d. In front of stage area. Although the demographics are not “mosh-pit” fans there is always a risk of overcrowding, crushing and possible fights between fans. Security (barrier) staff to monitor the situation and remain in contact with crowd control.
- e. Internal queuing near access points to seating area. Safety marshals to monitor, clear blockages (people sitting on steps, etc.) and remain in contact with crowd control.
- f. Queuing in front of F&B outlets. May hamper crowd flows if not managed properly. Safety marshals to monitor and remain in contact with crowd management and F&B manager.
- g. Queuing in front of Step 3 and Ramp during egress. Safety marshals to monitor, direct people to Step 1 and Step 2 and remain in contact with crowd control.

REFERENCES

- Cold Chisel Cause Concerns By: Natalie STAFFORD Date: 09/09/2011 <http://3degree.ecu.edu.au/articles/3944>
- Cheap wine and a 30-year growth - the '80s gets vocal by: Bernard Zuel Date: 23/07/2011
<http://www.smh.com.au/entertainment/music/cheap-wine-and-a-30year-growth-the-80s-gets-vocal-20110722-1hsuk.html#ixzz3Q5DwNHp7>

Eric Kant - Wantijpop

About Eric

Eric is the owner of Phase018 Crowd Management, a crowd safety consultancy in the Netherlands. Eric specialises in managing crowds in confined spaces and crowded places. He graduated from Manchester Metropolitan University with a master's degree in Crowd Safety and Risk Analysis (Crowd Science). Furthermore, Eric is a qualified agent-based modeller, certified by Lund's University. He has worked with Prof Still on many crowd counting projects, around the world.

Eric specialises in the various strategies that should be prepared for the emergency evacuation of large crowds and the associated effective crowd communication strategies. He is pragmatic and takes an evidence-based approach.

Eric has years of experience as an event safety specialist at the Dutch National Police where he provides expert advice to operational, tactical, and strategic commanders during the approval phase, preparation, and operational phase of major or high-risk public events, crises and mono/multidisciplinary operations. He was involved in hundreds of mass events: from national celebrations, concerts, and Christmas markets to Premiere league soccer fixtures and EDM festivals.

Introduction

“Wantijpop” is an annual single-day music festival held in a city park in Dordrecht, The Netherlands. The festival is named after the park where the festival takes place: “Wantijpark”. This report is based on the event plans of the “2015 edition”, as I had to approve as a police officer in the licensing phase of the event. At that time, I was not competent enough to explain the licensors that there might be something wrong with the design in relation to the occupant capacity. My primary concern was (and still is) the limited escape capacity from the main stage area in an emergency: rendering into high density crowd and congestion at the exits.

The fire department over-ruled my advice by claiming that the main stage area could be evacuated within 15 minutes and because of that “the site was fit for purpose”. The event took place in mid-June 2015 and no crowd incidents happened. According to the event calendar, the approval phase for the “2016 edition” will start in March 2016.

Key aspects of the event

The event is an annual recurring single day open air pop/rock festival. Admission is free but all persons and bags are subject to search by security staff. It is a “family and friends” festival attended by visitors of all ages. The festival has three areas: the main stage area, a secondary area with a smaller stage and a small area with a pop-up market. The festival is being

promoted across the country. There are well-known and lesser-known artists in the line-up. After previously held editions, several visitors complained about the main stage area as it was too crowded. It is unclear how many visitors attended at the previously held editions. At the official evaluation of the 2015 edition the organisation reported 17,000 visitors in total. In the press, the organisation claimed more as 20,000 visitors attended the 2015 edition.

In 2014, the organisation stated that 20,000 visitors attended the festival.

In 2015, the organisation stated there were more visitors as in 2014.

Since the festival is held in mid-June, temperatures can be high, and the event site (bushes, grass and trees) can be very dry. This results in an overall risk for fire.

Plan

Previously held editions of the festival were based on the same plans. The festival starts at 12.30h and stops at 23.00h. Entry gates open at 12.30h. The first artist (a local talent) at the main stage starts at 13.00h. The first headliner at the main stage starts at 16.00h. According to the official plan the event attracts 12,000 visitors in total and there will be 10,000 visitors on site at peak time. From previous editions we learned that most visitors gather at the main stage area.

The official AutoCAD map (Figure 100) shows the event site in black and white (black/coloured lines). From this AutoCAD map it is difficult to identify – for example – dense bushes (where it is impossible to walk), or

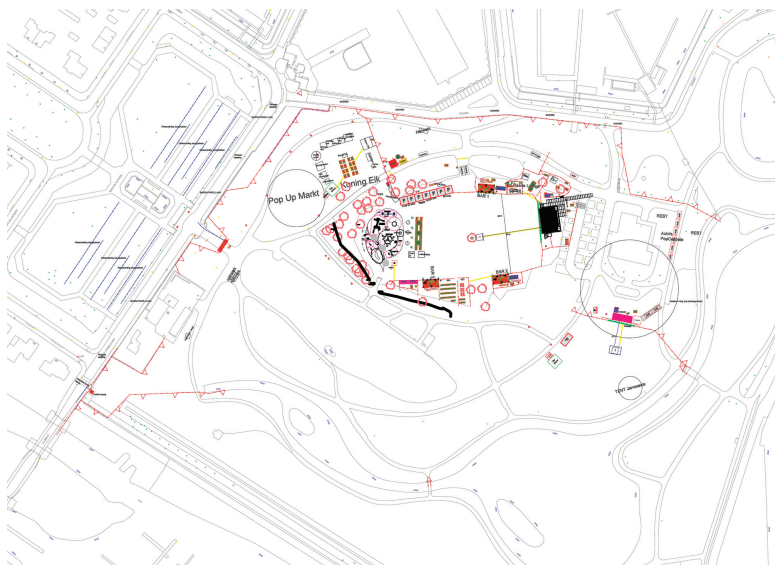


Figure 100 AutoCAD site map

to identify exits, footpaths or “pinch points”. Site, area or zone information, like sector/area capacity, static or dynamic zones, are missing. Entry points, exits, emergency exits and escape routes are not numbered or identifiable. The emergency evacuation and crowd management plan is flawed: “Inadequacies and deficient crowd management result in injuries and fatalities” (Fruin, 1993). For the sake of this report, I have numbered the exits and emergency exits (Figure 101).

Although large crowds “cannot be kept safe without some form of crowd monitoring” (Still, 2013: 110), there is a lack of monitoring actions.

Ingress

Most visitors arrive on foot or by bike. Cars and busses cannot come near the event site. Transport hub is located 900 metres (on foot) from the event site. Entry gates open at 12.30 h. Arriving visitors will not be counted during ingress. It is unclear if or when the management will decide to “close the gates” to prevent overcrowding. There will be a queue of visitors at the main point of entry, waiting to pass the entry elements for security check. Visitors are arriving in a constant flow between 12.00 h and 18.00 h. At 18.30 h most visitors are on site. When entered, most visitors take the shortest route to the main stage area.

Circulation

Most visitors gather at the main stage area. However, there will be a constant flow of visitors going to and from the secondary stage and pop-up market (Figure 102). Most facilities like toilets, food/drinks, cash desks and lockers are located at the main stage area.

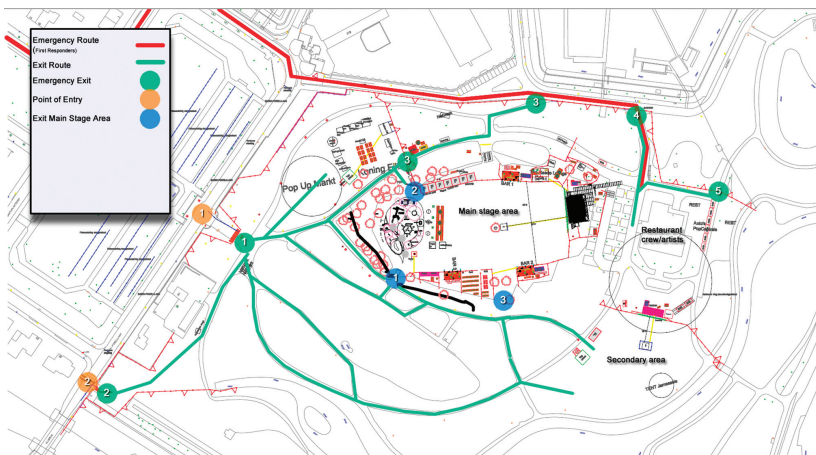


Figure 101 Map numbered exits

Egress

Egress starts at 10.30 pm and show ends at 11.00 pm. According to the “least effort” principle, it is predictable that most visitors take the shortest route to the final exit: “Individuals will take the shortest available route to get from source to destination. Where the ‘shortest’ is defined by shortest time (which may not be the shortest distance), an individual may walk around a high-density crowd to reach their objective in less time it takes to walk through the high-density crowd” (Still, 2013: 120). Moreover, the shortest route to the final exit is also the route most visitors use to enter the main stage area: via main stage area ‘Exit 1’ (Figure 101). Therefore it is predictable most visitors will use that same route to leave the area (Ellsberg’s paradox²⁰).

The main stage area has three exits (2.5m, 7.6m and 5.2m) leading to the exit route. The shortest route to the final exit leads through the smallest “Exit 1”. Congestion, specifically under emergency egress or flight response, is predictable at the main stage area “Exit 1”, “Exit 2” and at the final exit. In a normal situation it will take approximately one hour for all visitors to leave the site.

Emergency route

Because of some small bridges there is just one emergency route possible. The heavy fire-department trucks cannot pass these small bridges. The emergency route leads to the parking lot located at the backside of the main stage (Figure 101).



Figure 102 RAMP analysis. Routes, Circulation, Normal

²⁰ https://en.wikipedia.org/wiki/Ellsberg_paradox

Key aspects of the site

The festival is held in a city park in Dordrecht consisting of grass fields surrounded by dense bushes and (high) trees, a network of narrow bended asphalt footpaths and some water features (Figure 101). The borders of the park are marked by steel fences or dense bushes. According to the festival organization the total event site is net 10,000 m² from which 4,300 m² is the grass field where the main stage is located. Although the official event plan reports net 10,000 m² site, “only static and dynamic spaces should be considered for site capacity” (Still, 2013: 129). Entry points are used as final exits and emergency exits. “Entry points” to the main stage area is through three “openings in the bushes” that are exits from that area at the same time.

Fencing

The entire festival site is fenced off with two-meter-high festival fences.

Entrance

Entrance to the festival is via the main point of entry (6 metres wide) or via a secondary (smaller) entry point meant for families with strollers. Main point of entry is 6 metres wide and has 10 access control gates each 50 centimetres wide for security check. Located next to the access control gates there is one small 1 m exit. The secondary point of entry consists of two access control gates, 50 centimetres wide for security check.

All persons and bags are subject to search by security staff. On average it takes 20 seconds per visitor to be checked: 3 ppm x 12 access control gates = 36 ppm x 60 minutes = 2160 persons per hour. According to the official plan there will be 12,000 visitors maximum: $12,000/2160 = 5.5$ hours to get everyone on site.

Main stage area

The main stage area (4,300 m²) is in the centre of the park and is surrounded by dense bushes, trees, bars (food and drinks), mojo barriers and cash desks. The main stage area has three exits that lead to a network of narrow asphalt footpaths:

1. “Exit 1” (2.5 m) is most close to the final exit
2. “Exit 2” (7.6 m) is the widest exit and the closest to “Emergency Exit” (Figure 100)
3. “Exit 3” (5.2 m) is leading to a T junction (asphalt footpath)

Final exits

Final exit 1 is the main point of entry (Figure 101)

Final exit 2 is the secondary entry for families with strollers.

Emergency exits

According to the official plan there are five emergency exits (Figure 101):

“Emergency Exit 1” is the main point of entry

“Emergency Exit 2” is the secondary entry for families with strollers

“Emergency Exit 3” leads to the emergency route for first responders

“Emergency Exit 4” is not reachable for visitors, only for crew/artists

“Emergency Exit 5” is not reachable for visitors, only for crew/artists

DIM-ICE normal

Table 67 DIM-ICE Normal

<i>Normal</i>	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Design	Limited entry capacity: queuing/congestion	Overcrowding / congested spaces main stage area	Limited exit capacity of the main stage area
	Limited flow capacity (narrow footpaths)	Limited flow capacity (narrow footpaths)	Limited flow capacity (narrow footpaths)
	Risk for fire at high temperatures	Risk for fire at high temperatures	Congestion at exits main stage area
			Obstacles on the emergency exit route to exits 1 & 2
			Risk for fire at high temperatures
Information	No signage for arriving visitors approaching the event site	Exits of main stage area not clearly marked (signage)	Exits of main stage area not clearly marked (signage)
Management	Visitors are not counted: risk for overcrowding	No CCTV	No CCTV
	No CCTV	No queuing/ congestion management	No queuing/ congestion management
	No queuing/congestion management		

DIM-ICE emergency

Table 68 DIM-ICE Emergency

Emergency	Ingress	Circulation	Egress
Design	Entrances cannot be used as emergency exits	Overcrowding / congested spaces main stage area	Limited exit capacity of the main stage area leading to congestion
			Overall emergency exit capacity
			No alternatives in case of unusable exit main stage area
	Limited flow capacity (narrow footpaths)	Limited flow capacity (narrow footpaths)	Limited flow capacity (narrow footpaths)
	Risk for fire at high temperatures	Risk for fire at high temperatures	Obstacles on the emergency exit route to exits 1 & 2
			Emergency exit 3 leads to First Responders emergency route
			Risk for fire at high temperatures
Information	Limited number of loud hailer	Limited number of loud hailer	Limited number of loud hailer
	No use of signage	No use of signage	No use of signage
	Announcements via PA system will not cover entire site	Exits of main stage area not clearly marked (signage)	Escape routes are not clearly marked (signage/lights)
		Announcements via PA system will not cover entire site	Exits of main stage area not clearly marked (signage)
			Announcements via PA system will not cover entire site
Management	A detailed evacuation plan is missing	A detailed evacuation plan is missing	A detailed evacuation plan is missing
	No CCTV	No CCTV	No CCTV
	No queuing/congestion management	No queuing/congestion management	No queuing/congestion management
	Not enough stewards to assist in an emergency evacuation	Not enough stewards to assist in an emergency evacuation	Not enough stewards to assist in an emergency evacuation

Conclusions

1. The event site might not fit the purpose: Pop/rock festival with high number of visitors. Very limited possibilities to add additional:
 - Entry points (increase ingress capacity)
 - Alternative exits from main stage area (exit capacity)
 - Emergency exits (increase egress capacity during an emergency)
2. Based on the DIM-ICE matrix, Congestion-Risk map (Figure 103–106), RAMP Analysis and Dutch regulative norms the event plan should be rejected.



Figure 103 Congestion risk map 1200–1300

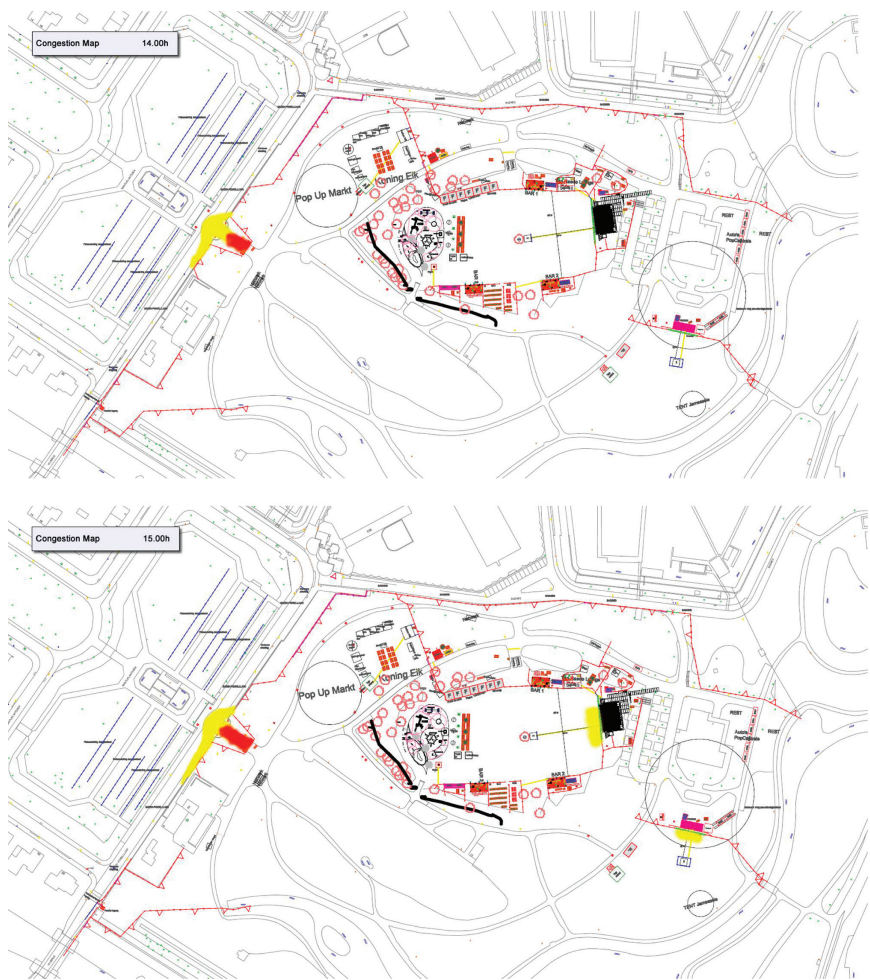


Figure 104 Congestion risk map I400–I500

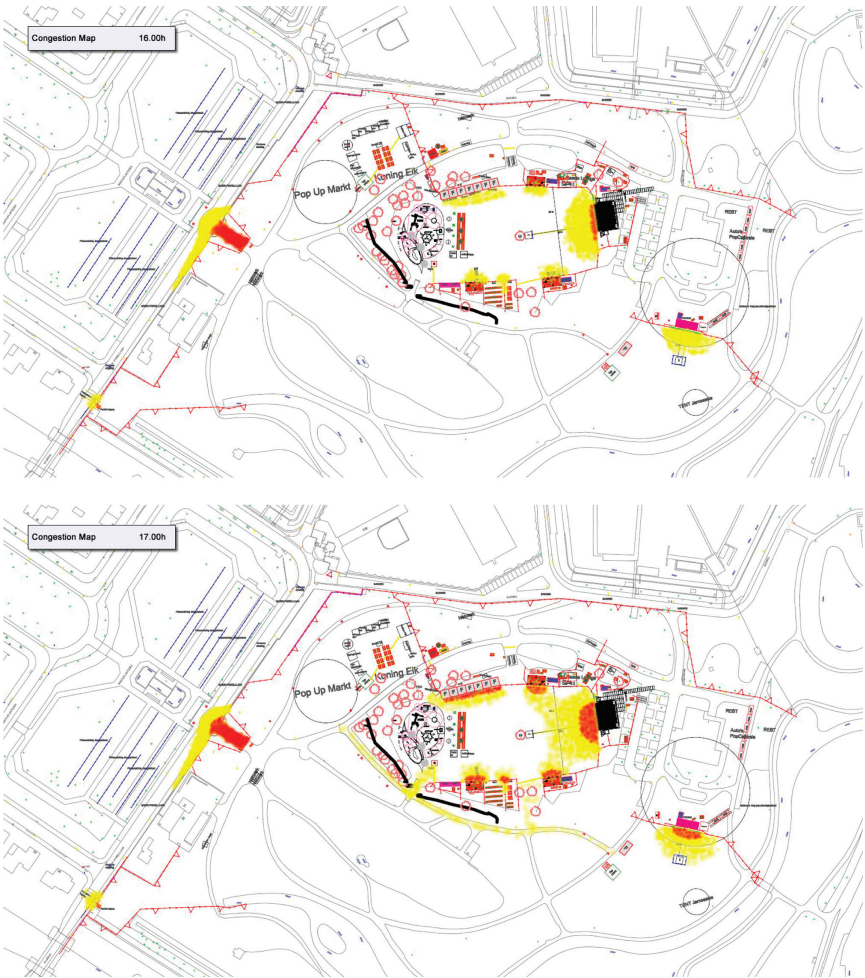


Figure 105 Congestion risk map 1600–1700

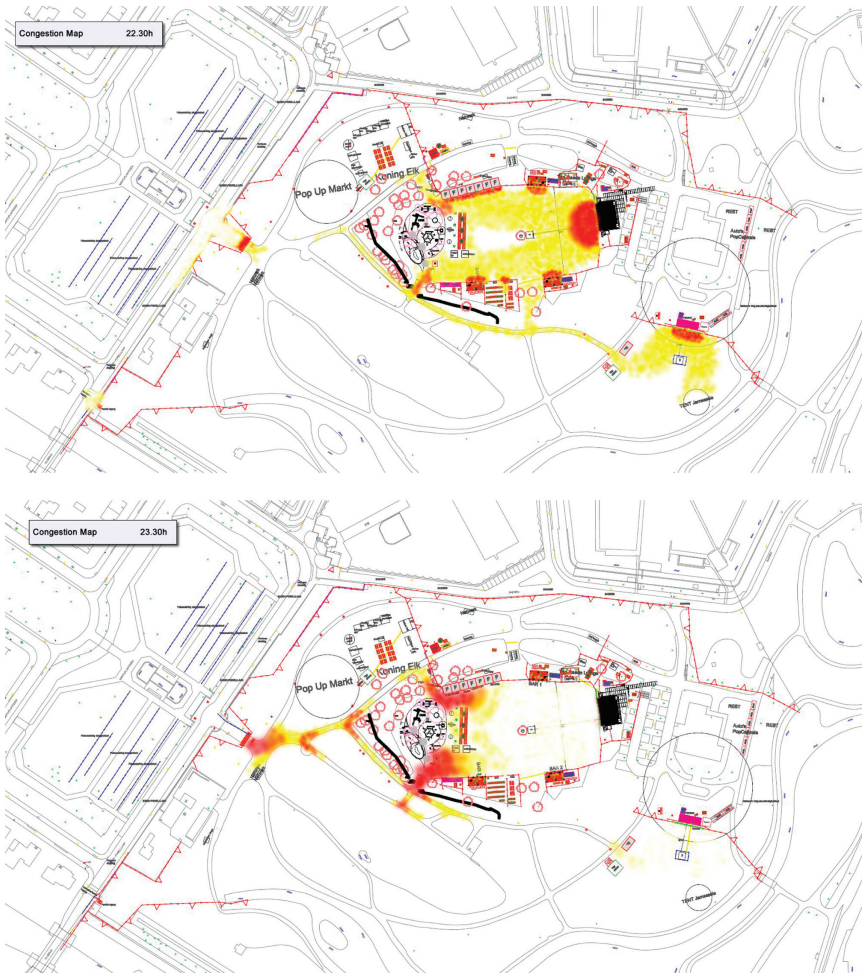


Figure 106 Congestion risk map 2230–2330

Primary risks:

DIM-ICE

- Visitors are not counted during ingress: risk for overcrowding
- A detailed evacuation plan is missing
- Not enough stewards to assist in an emergency evacuation
- Limited exit capacity of the main stage area rendering into congestion during egress under normal and emergency situations
- No alternative exits in case of unusable exit at main stage area
- Limited flow capacity of the narrow asphalt footpath network
- Emergency Exit 3 leads to First Responders emergency route (Figure 100) and should be discarded
- Escape routes are not clearly marked by signage or lights
- Exits of main stage area are not clearly marked by signage or lights
- Risk for fire at high temperatures



Figure 107 Ingress Risk (top) and Route (bottom) diagram



Figure 108 Circulation Risk (top) and Route (bottom) diagram



Figure 109 Egress Risk (top) and Route (bottom) diagram

RAMP Analysis:

Main point of entry cannot (immediately) be used as emergency exit during ingress and/or circulation.

- Limited ingress capacity rendering into high density crowd at main point of entry
- Limited exit capacity of the main stage area might render into congestion during egress under normal and emergency situations
- Limited flow capacity of the narrow asphalt footpath network
- Egress time under normal conditions of the main stage area (spectator facility) will exceed the regulative 8 minutes (NEN-EN 13200-7 (EN) p23) if visitor number is higher as 10,036 – considered all 3 main stage area exits are optimum utilised ($15.3\text{m exit width} \times 82 \text{ pers.} \times 8 \text{ minutes} = 10036$)

The total event site cannot be evacuated within the regulative 15 minutes (Infoblad Bouwbesluit (Infosheet Building Act NL, 2012 p3) if visitor number is higher as 8,430 – considered both emergency exits are optimally utilised ($12 \times 50\text{cm gates} = 480 \text{ ppm} + 82 \text{ ppm (1m exit)} = 562 \text{ ppm} \times 15 \text{ min} = 8,430 \text{ ppm}$).

Recommendations – Overall

To determine the maximum occupant capacity a capacity analysis should be conducted. Measures should be taken which will minimise the outbreak and spread of fire. Spectator accommodation which has a high fire risk should have an emergency exit capacity based on an emergency evacuation time of not more than two and a half minutes. “A longer emergency evacuation time, of between two and a half minutes and eight minutes, is acceptable for grounds or parts of grounds where the fire risk is reduced” (Guide to Safety at Sports Grounds p. 85).

Decision support analysis

The matrix approach provides useful insights into the best use and deployment of resources. The matrix approach not only focusses attention on key elements of time-related risks – it also highlights what most crowd management plans fail to address: that incidents can occur during ingress, mid-event and during egress (Still, 2013: 120). Look into an example of a matrix approach where location is outlined against the phase’s ingress, circulation or egress and predicts high-density crowds.

Table 69 Decision Support Analysis (Normal)

<i>Normal</i>	<i>Ingress</i>	<i>Circulation</i>	<i>Egress</i>
Main entry			
Secondary entry			
Pop-up market			
Main stage area			
-Front of stage			
-Front of house			
-Bars			
-Food			
-Lockers			
-Toilets			
-Cash decks			

(Continued)

Table 69 (Continued) Decision Support Analysis (Normal)

Normal	Ingress	Circulation	Egress
-Exit 1			
-Exit 2			
-Exit 3			
Secondary area			
-Front of stage			
-Bars			
-Toilets			
-Tents			
Footpath network			
Final exit 1			
Final exit 2			

Table 70 Decision Support Analysis (Emergency)

Emergency	Ingress	Circulation	Egress
Main entry			
Secondary entry			
Pop-up market			
Main stage area			
-Front of stage			
-Front of house			
-Bars			
-Food			
-Lockers			
-Toilets			
-Cash decks			
-Exit 1			
-Exit 2			
-Exit 3			
Secondary area			
-Front of stage			
-Bars			
-Toilets			
-Tents			
Footpath network			
Final exit 1			
Final exit 2			

Ingress

Visitors entering the event site should be accurately counted at their time of entry. Numbers require to be controlled to ensure that overcrowding does not occur. Provide visitors with clear information on all aspects of entry: “If there are design limits, then information helps reduce the risks and management may be required to control or regulate the approaching crowd flow” (Still, 2013: 163). Number entry points and make sure they are identifiable; prevent queuing at the entry points by changing design and/or increasing ingress capacity. Install CCTV for monitoring: “Real time information about the status of crowd conditions in large assembly spaces is critical” (Fruin, 1993: 1). In case of overcrowding, appropriate management procedures should be put in place: “Primary crowd management objectives are the avoidance of critical crowd densities and the triggering of rapid group movement” (Fruin, 1993: 6); use loudhailers to communicate with visitors: “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” (Fruin, 1993: 9). Prepare an emergency evacuation plan during ingress. Provide adequate lightning at ingress routes. Plan a sufficient number of competent stewards to assist in an emergency evacuation during ingress. Remove obstacles at ingress routes.

Circulation

Install CCTV for monitoring. Determine main stage area occupant capacity and count/control numbers to ensure that overcrowding does not occur. In case of overcrowding, appropriate management procedures should be put in place. Exits at main stage area should be clearly identifiable by signage and number. Use loudhailers to communicate with visitors. Provide clear information on all aspects of the site and festival. Prepare an emergency evacuation plan during circulation. Provide adequate lightning at circulation routes. Plan for enough competent stewards to assist in an emergency evacuation during circulation. Spread facilities (toilets, cash desks, lockers, etc.) over the site, instead of locating them all at the main stage area. Remove obstacles at circulation routes.

Egress

Install CCTV for monitoring. In case of overcrowding, appropriate management procedures should be put in place. Consider to close bars at 23.30h to spread egress. Provide information and apply management procedures to ensure optimum utilization of the exits at the main stage area, exit routes, emergency routes, emergency exits and final exits. Exits at

main stage area, emergency exits and final exits should be clearly identifiable by signage and number. Use loudhailers to communicate with visitors. Provide clear information on all aspects of exiting the site. Prepare an emergency evacuation plan during egress. Provide adequate lightning at exits, exit routes, emergency routes, emergency exits and final exits; remove obstacles at those routes and exits. Plan enough competent stewards to assist in an emergency evacuation during egress. Remove obstacles at exit/escape routes.

REFERENCES

- Fruin, J.J. (1993). The causes and prevention of crowd disasters. Originally presented at the First International Conference on Engineering for Crowd Safety, London, England, March 1993.
- Still, K. (2013). Introduction to Crowd Science. Boca Raton: CRC Press.
- NEN (2014). NEN-EN 13200-7:2014: Spectator facilities - Part 7: Entry and exit elements and routes <https://www.nen.nl/NEN-Shop-2/Standard/NENEN-1320072014-en.htm>
- Bouwbesluit (2012). Infoblad Vluchten bij brand <https://www.rijksoverheid.nl/documenten/brochures/2012/10/09/infoblad-bouwbesluit-2012-vluchten-bij-brand>

USM - NCS⁴

Imagine the action of a vaccine not just in terms of how it affects a single body, but also in terms of how it affects the collective body of a community. Eula Biss

The University of Southern Mississippi (USM)

Established in 2006, *the National Center for Spectator Sports Safety and Security* (NCS⁴) is the United States only academic centre devoted to the study and practice of spectator sports safety and security. The NCS⁴ is located at The University of Southern Mississippi (USM), a top-tier (R.I.) Carnegie Classified institution for its very high research activity. Only 130 universities and colleges in the United States have achieved this designation. The NCS⁴ mission supports the sports and entertainment industries through innovative research, training and outreach programs. The NCS⁴ works closely with diverse organizations and subject matter experts to better understand the threat environment, identify vulnerabilities, communicate risk-mitigation techniques and close capability gaps.

Training and education

In 2007, the NCS⁴ received its first training grant from the Department of Homeland Security (DHS) and the Federal Emergency Management Agency (FEMA) to develop and deliver a risk management course to build competencies in communities hosting sports and special events. In 2011, the NCS⁴ partnered with the Texas A&M Engineering Extension Service (TEEX) to expand the Centre's training capacity. The partnership offers grant-funded courses in risk management, incident management, communications, evacuation and emergency notification. As on 2021, the NCS⁴ has trained over 23,000 multi-disciplined professionals representing over 1,000 organizations responsible for the safety and security of sports and special events.

Since 2013, the NCS⁴ has offered professional development programs, including the Certified Sport Security Professional (CSSP) certification and the Certified Sports Venue Staff (CSVs) certification. The CSSP is targeted to individuals with leadership experience in the sports security industry. The CSVs certification recognises front-line venue and event staff who have completed standardised, role-specific training, which provides a baseline understanding of safety and security functions.

The NCS⁴ training and education portfolio expanded in 2016 on an international level through a partnership with INTERPOL – Project Stadia. The training agreement included developing and delivering coursework to police commanders and incident management leaders in INTERPOL's 194 member countries responsible for managing and policing safety and security at major international sporting events.

Crowd management training and resources in the United States

Prior to 2019, there were more than 124,000 public assembly areas operating in the United States. Additionally, there were over 420 million annual visitors to outdoor and major sporting league events alone, highlighting a need for communities and venues to create effective crowd movement and control plans using systematic best practices. Examples of current crowd management guidelines in the U.S. include, but are not limited to:

- ANSI ES1.9–2020
- NFPA 101
- Fire Safety in Assembly Occupancies
- OSHA Education Center
- 403.12 Special Requirements for Public Safety
- Commercial Facilities Sector-Specific Plan

A national training needs assessment conducted by the NCS⁴ in 2018 identified crowd management as a top training and resource need for communities and organizations hosting and managing sporting, entertainment and/or special events. Furthermore, a follow-up study, conducted in 2019, enabled the NCS⁴ to validate the need for crowd management training, identify and prioritise topical areas, and gauge the level of urgency for crowd management training and resources. The NCS⁴ began developing a nationally accredited and grant-funded crowd management course for a 2021 release in response to the industry's needs. Subsequently, the NCS⁴ formed a strategic partnership with Crowd Risk Analysis Ltd and world-renowned crowd science expert Professor Dr. G. Keith Still to offer a crowd safety management course to the North American market.

Research

The NCS⁴ is renowned for its DHS/FEMA and INTERPOL training programs, certifications, conference and forum events, and best practices resources. Another critical mission area focuses on applied research most impactful for the sports safety and security industry. Three primary research projects are underway, including:

Spectator Sports Safety and Security Survey – the purpose of this annual survey is to gauge sport spectators' perceptions of safety and security at events and their awareness of measures in place to help reduce and prevent problems. In addition, specific environmental issues will be addressed appropriately, for example, their willingness to return to events post-COVID-19. The sample population is spectators that have attended a live professional or collegiate event in the past three years.

Sports Safety and Security Venue Director Survey – an annual survey intended for Vice President's (or Directors) of Safety and Security and

Intercollegiate Athletic Directors and is specific to the operational side of safety and security. The survey addresses information related to venue usage and demographics, personnel, budget, training policies, security-related interactions with visitors, organizational responses to issues/problems and technology utilization.

National Venue Safety and Security Assessment – this research project utilises open-source geocoded, time-stamped police-recorded incident data to analyse crime and disorder patterns that emerge around professional sports venues. Insights related to when and where problems emerge are quantified to guide stakeholders' decision-making regarding resource allocation or potential interventions to reduce or prevent incidents.

The NCS⁴ also supports a Research Fellows Board, including faculty from institutions worldwide studying various disciplines such as criminal justice, economics, sport management, computer science, cybersecurity and geography. These fellows produce interdisciplinary research in the sports safety and security field, and the NCS⁴ promotes their work annually through an annual Research Impacts Practice Report. Recent research studies include demonstrating the relationship between seasonal influenza levels and the presence of sports and entertainment venues in U.S. cities; assessing fans' willingness to return to sports venues in light of public health measures and in-venue conditions such as the requirement to wear a mask; evaluating sport event labour issues during the COVID-19 pandemic; exploring the influence of stadia and the built environment on the spatial distribution of crime; and determining the competencies necessary to manage a crisis and lead an organization post-crisis.

The NCS⁴ pursues partnerships with academic institutions, professional associations, and government agencies nationally and internationally. The NCS⁴ leverages faculty and student expertise in various degree programs and institutes specifically on the USM campus, including the College of Business and Economic Development's nationally ranked MBA and Sport Management Programs, and the School of Criminal Justice, Forensic Science, and Security's Institute for Advanced Analytics and Security (IAAS). The MBA and Sport Management Programs offer an emphasis area in Sport Security Management.

Outreach

The NCS⁴ maintains a large and diverse repository of best practices for professional sports, intercollegiate sports, interscholastic sports, and marathon and endurance events. Additionally, the NCS⁴ offers many resources and networking opportunities through its annual conference and industry-specific forums, engages with industry partners to test technological solutions through product reviews and operational exercises, and educates the marketplace through a webinar series.

FINAL WORD

“Science isn’t finished until it’s communicated. The communication to wider audiences is part of the job of being a scientist, and so how you communicate is absolutely vital.”.

Sir Mark Walport, UK chief scientist.

If you have enjoyed this addendum, and learned something useful, something that will help you improve your crowd safety and your crowd risk analysis, please spread the word.

— End —