Events, mass gatherings, and places of public assembly. Can traditional views and tools for crowd management assist in implementing non-pharmaceutical interventions to prevent the transfer of respiratory viruses such as COVID-19?

by

Bert Bruyninckx

Manchester Metropolitan University

School of Operations, Technology, Events and Hospitality Management

Submitted to Manchester Metropolitan University
School of Operations, Technology, Events and Hospitality Management
as part of the requirement of the MSc Crowd Safety & Risk Analysis

Date: 19/04/2021

Student ID: 16062333

Supervisor: Shaun Litler

Bert Bruyninckx

Acknowledgements

I would like to take this chance to express my gratitude to Professor Dr Keith Still who first of all inspired me to take on the course and lead me through an amazing journey if knowledge gathering and some interesting student projects. Thank you for your insights, advice and patience.

Thanks to the staff of Manchester metropolitan University to guide me to this dissertation process. Special thanks go out to Shaun Littler my supervisor. Thank you, Shaun, for your endless patience and last-minute talks and read throughs.

Further a would like to thank my fellow students at MMU for the nightly talks and WhatsApp conversations where we shared ideas, visions and best practices and of course thank you for the occasional beer when we were in Manchester.

Finally, I want to thank my friends and colleagues who had to put up with my endless talking about crowds and that weird science nobody ever heard of. A big thank you to those, and you know who you are, that proofread endless new versions of ma papers during my time at MMU.

Abstract

In 2020 the world was struck y the covid-19 pandemic, and in many places, society came to a standstill. Mass gatherings and events were cancelled, and places of public assembly became of interest to those managing public health. In expectation of a medicine or vaccine, under the guidance of the WHO, the world has adopted three main non-pharmaceutical interventions (1) physical distancing, Personal Protection Equipment such as face coverings, and (3) hygiene. The interventions are embedded in legislation throughout the world. Legislation and regulation, however, did not include the 'how'. Government guidance on how to achieve or facilitate distancing, the use of PPE's and strong hygiene is limited.

These non-pharmaceutical interventions are behavioural interventions. Physical distancing touches the field of crowd management. The area assigned to an individual and the organisation of public places is the common ground between crowd management and physical distancing.

This research aims to determine if the traditional elements of crowd management and the tools to manage crowds are useful in coping with the possible transfer of respiratory viruses on events, mass gatherings and places of public assembly. Expert interviews aimed to investigate how crowd managers implement the concept of physical distancing in their operations under covid-19.

Covid-19 and the need to plan for physical distancing did not affect the way crowd management was practised. The traditional theories still stand, and the same tools are used. The change is in the underlying variables of the tools. Physical distancing meddles with density and the area needed per person. Embedding these new thresholds based on the distancing value as laid out by government makes the traditional crowd management tools covid proof. Otherwise, trivial processes and event facilities became of interest. The entire customer journey has become the field of the crowd manager.

The research has resulted in a systematic approach for those managing events, mass gatherings and places of public assembly. This 'Covid Concept Planning Process' embeds traditional risk analysis methods and pedestrian panning and takes the user step by step to the development of measures to cope with physical distancing. With each step, crowd management tools are suggested.

TABLE OF CONTENTS

I LIST OF TABLES

II LIST OF FIGURES

1 Introduction and background to the study

1.1 Background to this research

Throughout history, humans have been gathering for survival purposes (Van Loon, 1921), commercially, politically or religiously reasons and for entertainment. Think about the games held for 50.000 people in the colosseum (Upton, 2004; Lomas and Cornell, 2005), the funeral of Sir Arthur Wellesley in 1852 with about 1.5 million people (Haghe, 1854) or more recent the funeral procession for General Qassem Soleimani's in Iran (Al Jazeera, 2020), social protests during the industrial revolution (Le Bon, 1895; Rude, 2005), religious gatherings in Kumbh Mela or Macca. In the last century, crowds at events have become common. Sports events, music or cultural festivals events attracting big crowds have become part of our modern way of life.

Occasionally the combination of inadequate facilities and deficient crowd management leads to injury and death (Fruin, 1993). These crowd incidents are examined by both academia and the events industry to determine the elements of crowd safety and to understand crowd dynamics. Within the field of crowd dynamics and the interdisciplinary discipline of crowd science (Still, 2020), a series of tools have been developed to manage crowds.

In December 2019, a new severe acute respiratory virus called SARS-COV-2 emerged in Wuhan, China (Bogoch et al., 2020; Lu et al., 2020). In early 2020 the virus spread worldwide, and the disease was called COVID-19 (World Health Organization, 2020e). Even before the pandemic declaration, on March 11, 2020, the World Health Organisation (WHO) (2020i) related the outbreak with risk assessments for Mass Gatherings (World Health Organization, 2020c), as history has shown that mass gatherings and events can spread diseases on a global level (McCloskey et al., 2020). WHO (2020b) does not recommend all mass gatherings to be cancelled. However, the non-pharmaceutical intervention of social distancing (European Centre for Disease Prevention, 2020; World Health Organization, 2020f, 2020a), as a means to stop transmitting the virus contradicts the essence of mass gatherings and events and is

impossible to impose (Ahmed and Memish, 2020; Memish et al., 2020). As a result, WHO states that postponing or reducing mass gatherings internationally should be seriously considered to control the spread of the virus. Many countries have prohibited events, numerous major conferences, festivals and sporting events by cancelling or postponing(Chin, 2020; Garcia et al., 2020) These actions have caused extraordinary economic losses worldwide (Escher, 2020), for example in the small country of Belgium the event industry faces an estimated 4.9 billion euro loss (Merckx and Desmedt, 2020).

1.2 Objectives of this research

This study researches if the traditional elements of crowd safety and the tools to manage crowds are useful in coping with the possible transfer of respiratory viruses, such as COVID-19, on events, mass gatherings and places of public assembly.

The objectives of the study are:

1. To critically review the academic literature regarding the transfer of respiratory viruses, such as COVID-19 and the non-pharmaceutical interventions to prevent transfer.
2. To critically review the academic literature regarding crowd safety and crowd management tools.
3. To investigate expert practitioners' views and experiences (event managers, safety/security managers, licensers) when implementing crowd safety and crowd management tools.
4. To analyse if and how events, mass gatherings, and places of public assembly embed the traditional views and methodology on crowd safety and crowd management to implement non-pharmaceutical interventions to prevent the transfer of respiratory viruses such as COVID-19.
5. To draw conclusions and make recommendations to event(safety) managers on the future strategy for coping with events and places of public assembly in the case of respiratory virus outbreaks.

1.3 Structure

This research consists of five chapters. The first introductory chapter sketches the background and context while outlining the five research objectives. The literature review in the second chapter is categorised into literature on crowd safety and crowd management tools is reviewed, and the literature on COVID-19 and possible non-pharmaceutical interventions is studied. The literature review provides the answers for objective 1 and 2. The third chapter elaborates on the used methodology to meet the objectives. The primary research, chapter four, seeks the answer to research objective four within the light of the literature review's insights. The findings, conclusions and suggestions for further research go in the fifth chapter.

2 Literature Review

2.1 Severe Acute Respiratory Syndrome CoronaVirus-2

2.1.1 SARS-CoV-2

In December 2019, Wuhan, China, saw many pneumonia cases of unknown aetiology (Bogoch et al., 2020; Lu et al., 2020; Rothan and Byrareddy, 2020; Zhu et al., 2020). A new-type of β-coronavirus of the Coronovaridae family, initially called 2019-nCoV by the WHO (Hui et al., 2020; Lu et al., 2020) and later officially renamed to Severe Acute Respiratory Syndrome Coronavirus-2, SARS-CoV-2, by the Coronavirus Study Group (CSG) of the International Committee on Taxonomy of Viruses (Gorbalenya et al., 2020) causes “novel coronavirus-infected pneumonia” (NCIP) (Zhu et al., 2020). WHO (2020e), later, renames the disease Corona Virus Disease 2019, COVID-19 in short. Other acute-lung-injury causing coronaviruses of zoonotic origin are SARS-CoV and MERS-CoV (Rothan and Byrareddy, 2020; Sciensano, 2020a; Zhu et al., 2020). Together with influenza and other HCoV viruses, it is catalogued as a winter virus (Moriyama et al., 2020).

The incubation period, the period between infection and symptoms, for COVID-19, first (January 2020) estimated between 2.1 days and 11 days with a mean of 6.4 (Backer et al., 2020; Lai et al., 2020) was later adjusted to an average of 5.2 days (Lauer et al., 2020; Q. Li et al., 2020; Rothan and Byrareddy, 2020). However, the virus's clinical latency is uncertain (Sciensano, 2020b); Li et al. (2020) put this on 3.47 days. This complies with the asymptomatic (Bai et al., 2020; Ganyani et al., 2020; Goldberg et al., 2020; Lai et al., 2020; Pan et al., 2020; Wei, 2020; Xu et al., 2020; Young et al., 2020) or pre-symptomatic (Asadi et al., 2020) spreading of the virus despite the findings of Gao et al. (2020). It is also unknown when the contagious period ends (Sciensano, 2020b).

The period between the first symptoms and (possible) death ranges from 6 to 41 days with a median of 14 days, comparable with MERS, but shorter than SARS with 17.4 days (W. Wang et al., 2020), depending on age and physical condition (Huang et al., 2020; Rothan and Byrareddy, 2020). The primary symptoms of COVID-19 are (1) fever, (2) cough, and (3)

shortness of breath/difficult breathing (dyspnoea); other symptoms are (4) sputum production, (5) headache, (6) coughing up of blood (haemoptysis), (7) diarrhoea, (8) muscle ache and (9) shortage of white blood cells (lymphopenia) (Chen et al., 2020; Huang et al., 2020; Ren et al., 2020; Rothan and Byrareddy, 2020; Xu et al., 2020).

2.1.2 Transmission of Respiratory Viruses

The average, expected number of additional infected people that one person will generate during the infectious period in a fully susceptible population is called the basic reproductive number, R_0 (Q. Li et al., 2020). R_0 for COVID-19 sits between 2 and 4 (Alimohamadi et al., 2020; Liu et al., 2020; R. Li et al., 2020; Sciensano, 2020b), more contagious than other respiratory viruses such as SARS and MERS (Chen, 2020; Petrosillo et al., 2020). At the beginning of the outbreak in Belgium, R_0 was set on 3 (Devroey, 2020).

The estimated contagiousness, the effective reproduction number (R_e), at a given time with the then prevailing measures (Sciensano, 2021) evolves as a function of the population immunity and human behaviour (Mahase, 2020). To control the epidemic, R_e needs to be < 0. WHO (2020j) declares an epidemic over when no new cases are presented in a period of two times the maximal incubation period; for COVID-19, this means 28 days without new cases.

To decrease R_e, the transfer of the virus between people is to be suppressed (World Health Organization, 2020h); therefore, it is critical to understand the transmission of SARS-COV-2. Respiratory viruses replicate in the upper respiratory tract (Wölfel et al., 2020) and, in general, have two main ways of transfer via (1) respiratory droplets and (2) via fomites (Crowe, 2008). Evidence indicates that SARS-CoV-2 is transmitted in the same way (Pica and Bouvier, 2012; Yu et al., 2014; Xiao et al., 2017; Kutter et al., 2018). With gastrointestinal symptoms such as diarrhoea, the possibility of faeceo-oral transmission, as with SARS, is to be studied as well (Huang et al., 2020; Rothan and Byrareddy, 2020; World Health Organization, 2020d). Infection occurs when the droplets or droplet nuclei settle on the mucous membrane of the eyes, nose or mouth or by inhalation (Boone and Gerba, 2007; Moriyama et al., 2020) and takes place either at home (1/3 of the cases), at schools or workplaces (1/3 of the cases), and in the community (Ferguson et al., 2006)

Primarly, transmission occurs through droplets or direct contact (Rothan and Byrareddy, 2020). Droplets can be emitted by talking, coughing, sneezing (Fernstrom and Goldblatt, 2013; Moriyama et al., 2020; World Health Organization, 2020d) or even breathing (Johnson et al., 2011). WHO (2020d) and Fernstrom and Goldblatt (2013) mention a spread of 1m (3 feet) for droplets; Moriyama et al. (2020:4) refers to this distance as '…short-range..'. However, Bahl et al. (2020) argue that droplets travel up to 8 meters, further than assumed by the WHO, CDC and European Centre for Disease Control.

Smaller droplet-nuclei can be ejected over a distance of 8 meters (Bahl et al., 2020; Bourouiba, 2020), can stay longer airborne and can travel longer distances, up to 30 meters (Gorbunov, 2020). These aerosol nuclei expose a higher number of people (Fernstrom and Goldblatt, 2013) to viable virus particles (van Doremalen et al., 2020). Evidence of this mechanism with SARS-CoV-2 is incomplete and not validated (Carducci et al., 2020) and might be exaggerated (Goldman, 2020). The precautionary principle should be applied (Carducci et al., 2020; Crosby and Crosby, 2020) with further studies into transfer via the aerosol (Bahl et al., 2020; Moriyama et al., 2020; Rothan and Byrareddy, 2020; van Doremalen et al., 2020; World Health Organization, 2020g, 2020h). The difference between droplets (> 5 µm) and aerosols (< 5 µm) lies in the size of the particle and thus the time it stays in the air and the distance it can travel (Pica and Bouvier, 2012; Fernstrom and Goldblatt, 2013; Kutter et al., 2018; World Health Organization, 2020h).

Droplets	**Aerosols – droplet Nuclei**
> 5 µm	< 5µm
Coughing, sneezing, talking (< 1m)	Slow settling velocity, stay in air longer > 1m

Table 1: Transmission of SARS-COV-2

Droplets can end up on objects or surfaces. Transfer of the virus is possible when a susceptible person comes in contact with contaminated fomites (Lewis, 2020; van Doremalen et al., 2020) and touches the eyes, nose or mouth (Boone and Gerba, 2007). The time the virus remains stable depends on the surface material and the environmental conditions (van Doremalen et al., 2020).

2.2 Human Behaviour

2.2.1 The Le Bonian tradition

Le Bon (1895), an aristocrat of the late eighteen hundreds who saw the crowd as a threat to civilisation and social order (Holton, 1978; McPhail, 1991; Sande, 2013), decontextualizes the crowd (Reicher, 2008) and depicts crowds as emotional, irrational, suggestible of low moral standard and potentially dangerous. This, the anonymity in a crowd and the idea that one individual's state of mind can spread to another's without a conscious effort form the basis for Le Bon's (1895) Theory of Contagion and Park and Burgess' (1921) process of Circular Reactions. Turner and Killian (1972) do not subscribe to the irrationality within crowds but state that crowds are highly suggestible. Their Emergent Norm Theory suggests that less stable crowds, such as expressive crowds (McPhail, 1989) have norms that may be vague and changing (Park, 1967). When individuals are in a vague, confusing, or ambiguous situation, new norms emerge instantly; those new emergent norms may not be in line with normal behaviour (Turner and Killian, 1972). Berlonghi (1995) refers to the Le Bonian ideas by addressing deindividuation and the loss of self-awareness as a characteristic of crowds, where the ability to act rationally is lost (Festinger et al., 1952). Despite not being supported by evidence (Schweingruber and Wohlstein, 2005), the Theory of Contagion, the Emergent Norm Theory and the idea of a crowd being irrational, uncontrollable and dangerous are adopted and accepted by sociology, the general public (Schweingruber and Wohlstein, 2005), and disaster research (Mariel and Arthur, 2013).

2.2.2 Emergency Situations: from Mass Panic to a Shared Social Identity

All Quarentelli's (1954, 1960) five definitions of panic from the field of sociology and psychology described by Fahy et al. (2009), and the academic definitions of panic as summarised by Rogsch et al. (2010) define that the concept of panic embeds an acute, uncontrollable, excessive fear causing irrational and non-social behaviour that dominates reason. A distinction is to be made between mass and individual panic (Nogami, 2018). The crowds' characteristics of irrationality, emotionality and suggestibility (Le Bon, 1895) are often translated in the myth of panic rapidly spreading through the crowd, resulting in mass panic and explaining people's

response to danger (Tong and Canter, 1985). Fear and panic are often wrongfully interchangeably used to describe people's reactions in disasters (Gantt and Gantt, 2012). Panic is rarely a large scale or collective response (Quarantelli, 1960; Sime, 1983; Johnson, 1988; Clarke, 2002; Fischer, 2002; Drury and Cocking, 2007; Drury, 2011; Cocking and Drury, 2014) and resisting the urge to irrationality is the norm (Dean, 2009). Late or underreaction to a threat or cue to action are more common (Atwood and Major, 2000 in Drury, 2020).

In case of emergency, often physical crowds transform into psychological crowds due to '…an experience of common faith' (Reicher, 2011; von Sivers et al., 2014). Psychological crowds share a social identity (Drury and Reicher, 1999; von Sivers et al., 2014; Templeton et al., 2015, 2018) without losing their individual identity. As Le Bon (1895) suggested, turning irrational, losing control or self-interest and become difficult to guide or steer in an evacuation through information or management as implied by Still (2014a). In a psychological crowd, behaviour and interest are focused on the collective self (Drury and Reicher, 1999). Drury, Cocking and Reicher (Drury and Cocking, 2007; Drury and Reicher, 2010; Drury, 2011) found that in cases of terrorist attacks, there is no evidence of panic-related actions (Cocking, 2016). The reaction of flight and mass evacuation behaviour can be explained as normative (Turner and Killian, 1957; Drury and Stott, 2011) and can be a very rational and appropriate response (Fahy et al., 2009). This all indicates that the model of 'Collective Resilience' (Drury et al., 2009, 2015; Cocking, 2016) and shared social identity (Drury and Reicher, 1999; von Sivers et al., 2014; Templeton et al., 2015, 2018) explain crowd behaviour in emergencies more accurate than the traditional model of crowd irrationality and mass panic (Le Bon, 1895). In extension, bystanders are found to assist and help (Donald and Canter, 1992; Drury and Cocking, 2007; Cocking and Drury, 2008) rather than be apathetic as suggested by earlier research (Darley and Latane, 1968; Manning et al., 2007).

2.2.3 Shared Social Identity in case of Pandemic

The common faith of the pandemic is the parallel between human behaviour in 'general' emergencies and the response to the COVID-19 pandemic (Drury, 2020) and has the potential to create a shared social identity (Drury and Reicher, 1999; Reicher, 2011; von Sivers et al.,

2014; Templeton et al., 2015, 2018). As long as a vaccine or medication is not readily available, people's behaviour and compliance with non-pharmaceutical interventions are key (Bonell et al., 2020; Drury, 2020; Flaxman et al., 2020; Jetten et al., 2020; Mahase, 2020). To succeed, this shared social identity must be nurtured, and to decide most rational (Canter et al., 1990; Cepolina, 2005), the public must be provided with “clear and credible risk information from a trusted source” (Drury, 2020:4), government or the spokesperson must be, or become in-group (Drury, 2003; Reicher, 2011; Drury et al., 2019; Elcheroth and Drury, 2020). The delay of communication or withholding information to prevent ‘panic’ is of no use (Clarke, 2002). It is the perception of the situation and the risks involved that are the basis of the crowd’s decision-making process (Purser and Bensilum, 2001; Kuligowski, 2008; Challenger et al., 2010a; Ronchi and Nilsson, 2016; Society of Fire Protection Engineers, 2018). The cue to action, to comply with regulations, must be perceived and interpreted as real and applicable to themselves or loved ones (Kuligowski, 2008). Ideally, the non-pharmaceutical interventions of (1) personal Hygiene, (2) mouth-nose masks, and (3) distancing become the group norm.

2.3 COVID-19: Non-Pharmaceutical Interventions

2.3.1 Hygiene

Patel et al. (2020) and the Belgian APB (Algemeen Pharmaceutische Bond, 2020) note (1) that viruses such as SARS, MERS and HCov are fast and efficiently deactivated with the use of 62% to 72% ethanol, 0.5% hydrogen peroxide or 0.1% sodium hypochlorite; and (2) that the disinfection of frequently touched surfaces is critical to limit fomite or indirect transfer. Next to this, both hand hygiene and respiratory and cough hygiene are essential to limit the spread of COVID-19 (European Centre for Disease Prevention, 2020; Lai et al., 2020; Public Health England, 2020).

2.3.2 Mouth-nose Masks

Howard et al. state that the use of face masks by the public reduces SARS-COV-2 transmission but the use of face masks for the general public and the evidence regarding the effectiveness is debated (Block et al., 2020; Jefferson et al., 2020). Guidelines on the use of

face masks vary between countries from the start of the pandemic (Feng et al., 2020). However, the precautionary principle (EU Publications Office, 2016) dictates the legitimacy of the obligated use of face masks (Crosby and Crosby, 2020; Greenhalgh et al., 2020).

2.3.3 Distancing

In the case of respiratory viruses such as the Influenza virus (Glass et al., 2006) and SARS (Ferguson et al., 2006; Block et al., 2020), social distancing is a well-known strategy to flatten the curve (Germann et al., 2006; Bolton et al., 2012; Block et al., 2020; Cowling et al., 2020; Greenstone and Nigam, 2020; Lewnard and Lo, 2020). (1) Social distancing is proposed as one of four community interventions, next to (2) travel restrictions, (3) school closure, and (4) quarantining (Bolton et al., 2012; Bai et al., 2020; European Centre for Disease Prevention, 2020).

The WHO (2020f, 2020a) proposed social distancing as a means to minimise the chance of COVID-19 infections by '…droplets generated when an infected person coughs or sneezes, or through droplets of saliva or discharge from the nose', and suggests keeping at least 1-meter distance. Nicoll et al. (2012) further state that, in essence, social distancing is a manner to decrease interpersonal or intergroup interaction. Whereas WHO (2020i) nuances and suggests that keeping physical distance does not necessarily equal social distance.

All European countries implemented physical distancing; Figure 1 shows the European applied values. Appendix G holds the data. However, Ronchi and Lovregio (2020) stress that policy often is based on macroscopic analysis of the virus spread and not designed for distancing performance on building or event level, micro modelling pedestrians and their environment. However, this can be used to assess exposure and the risk of transmission of SARS-CoV-2. The key is to minimise physical interactions between people (Anderson and May, 2010).

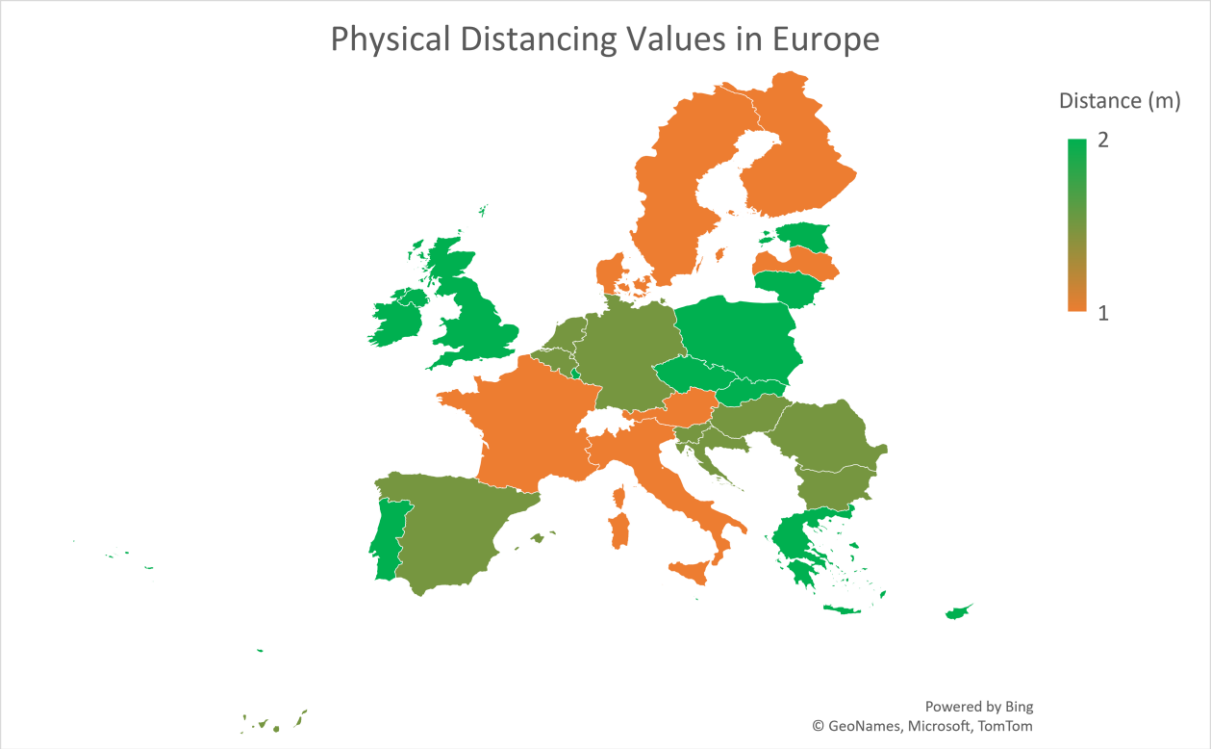


Figure 1: European Physical Distance values

2.4 Crowd Management, Crowd Dynamics and Crowd Science

Literature provides different definitions of crowd management. Fruin (1993:6) defines crowd management as

'…the systematic planning for, and supervision of, the orderly movement and assembly of people. … Crowd management involves the assessment of the people handling capabilities of a space prior to use. It includes evaluation of projected levels of occupancy, adequacy of means of ingress and egress, processing procedures such as ticket collection, and expected types of activities and group behavior'.

Tatrai (2001) links successful crowd management to effective risk management and a good understanding of crowd behaviour and design, while Berlonghi (1995) and van de Sande (2013) add the element of facilitating the movement and enjoyment of people to the definition.

Bellomo et al. (2016:3) give a more abstract definition by stating that crowd management:

‘…involves accessing and interpreting a wide variety of information sources, predicting crowd behaviour as well as for deciding the use of a range of possible, highly context-dependent intervention mechanisms.’

Similarly, The Australian Entertainment Safety Resource Guide (2017) relates crowd management to techniques and equipment to pro-actively influence crowd behaviour and manage crowd flow with the finality of reducing crowd-related risks. The guide adds that crowd management does not use force to influence crowd behaviour and touches the distinction between crowd management and crowd control. ‘Crowd Control is restrictive, limits the crowds’ behaviour’ (Fruin, 1993) and can be imposed by (police) force.

Still (2000) argues that the essence of crowd dynamics is:

> ‘…the study of how and where crowds are formed and move above the critical density of more than one person per square meter.’ (Still, 2000:1)

This definition aligns with Fruins’ (1993), Berlonghi’s (1995) and van de Sande’s (2013) definitions of crowd management.

By adding the elements of risk assessment, as also suggested by Tatrai (2001), emergency planning, information systems, human psychology and spatial awareness, crowd dynamics evolved into Crowd Science (Still, 2009). The addition of the psychological element aligns with Fruin’s (1993), Sime’s (1985) and Bellomo et al.’s (2016) vision that in crowd safety, both a psychological and an engineering angle are needed. Based on Stills work, Raineri (2016) puts the effect of crowd density, crowd dynamics and crowd individual and collective behaviour at the core of Crowd Science.

All definitions and descriptions embed (1) the element of preparation or planning, (2) the element of supervision or management, (3) the distinction between movement and assembly, (4) a link with design or context, (5) the importance of human behaviour and psychology, and (6) the intention of managing risk.

2.5 Managing Risks

WHO (2015, 2020f) states that respiratory viruses raise the highest level of concern with mass gatherings. On the other hand, McClosky et al. (2020) warn for the precautionary approach as it could be counterproductive. It is a context-specific risk assessment that should be the basis for cancelling events (World Health Organization, 2020c). An in-depth risk analysis is a fundamental part of an integrated safety and security approach and is required to develop a professional safety and security plan for an event (van Duykeren, 2012). It is, however, important not to limit the risk management process to disease or transfer related risks (Frankopan, 2020). In both the scientific community and the media, the use and interpretation of 'Risk' vary (Rausand, 2011; Wall, 2011). The Society of Risk Analysis states that each should define 'risk' in its own way (Kaplan, 1997). Risk is, however, associated with likelihood (Kaplan and Garrick, 1981; Duijm, 2015) or possibility (Elms, 1992) and potential damage (Kinney and Wiruth, 1976; Kaplan and Garrick, 1981; Government of Canada, 2019). Coleman and Marks (1999) and Rausand (2011) accept the view of Kaplan and Garrick (1981) by defining risk as the combined answer to the three main questions of risk assessment:

1. What can go wrong?
2. What is the likelihood of that happening?
3. What are the consequences?

Within the context of mass gatherings and events, Berlonghi (1993) describes the (1) identification of risks and potential losses, (2) the examination of measures to prevent damage, (3) the selection and planning of measures, (4) the implementation of measures, and (5) monitoring and evaluation of the actions taken as the five steps in the risk management process. This approach aligns with the risk assessment for public venues (Au et al., 1993) and the ISO 31000 Risk Management process (Figure 2). These processes are robust, systematic and embed a continuous process (Raineri, 2015), supporting the fact that Risk Assessments represent the situation at a particular moment in time and that risks are dynamic (Pullan and Murray-Webster, 2017).

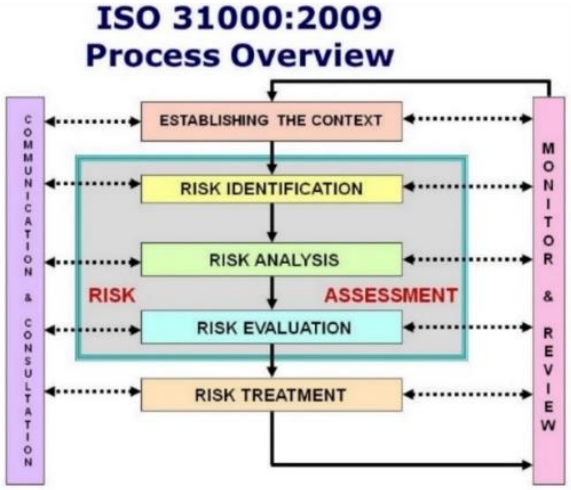


Figure 2 Risk Management Process - 31000:2009

The first step in the Risk Assessment sequence is the permanent and systematic identification of risks and provides an answer to the question of what can go wrong. Next, the core of the Risk Management Process (Raineri, 2015) is assessing the risks. It allows for prioritisation (Hubbard, 2009) and applying resources to avoid, mitigate, transfer or accept the risk (Ackx and Duijndam, 2006). A similar approach can be found in the Pedestrian Planning Process as defined by Fruin (1987), see Figure 3.

Risk analysis needs to be performed by professionals with adequate experience and access to all event information and details (Still, 2014a), and must incorporate the psychological aspect of crowd behaviour (Sime, 1985, 1995; Au et al., 1993; Raineri, 2013b, 2013a; Still, 2014a).

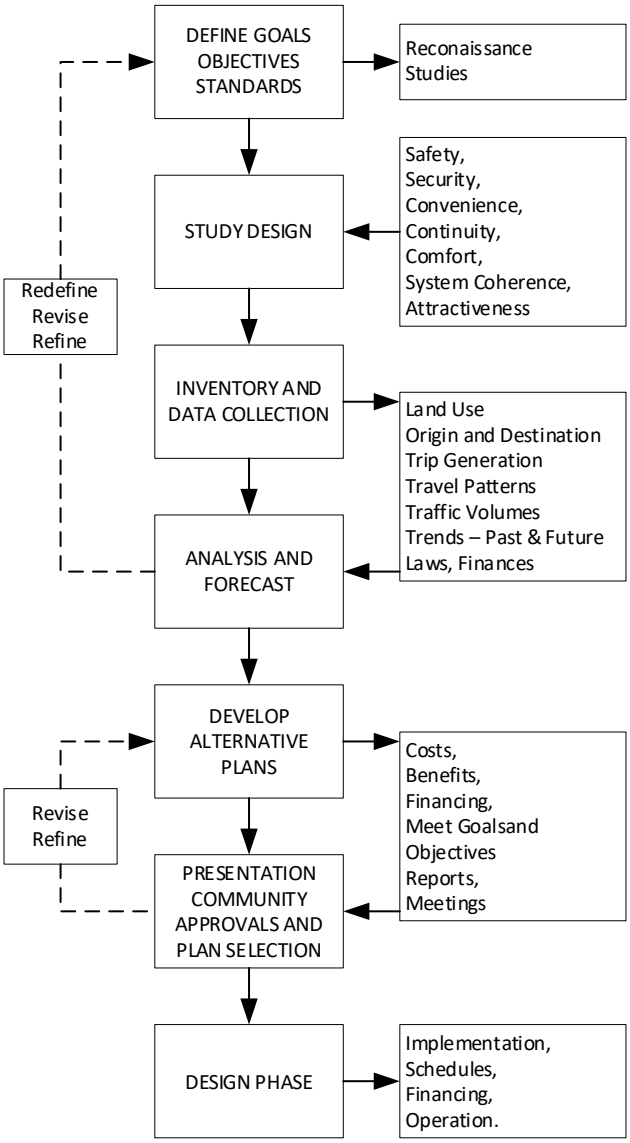


Figure 3: Pedestrian Planning Process - redrawn from Fruin (1987)

Quantitative Risk Assessments assign numerical values to the variables within the Kaplan and Garret questions (Rausand, 2011). Despite being questioned for being misleading and subjective (Dillen, 2009; Babut et al., 2011; Still, 2014b; Raineri, 2015), in Belgium, the Kinney and Kinney-Type methods are the norms (Malchaire and Koob, 2006).

Qualitative Risk Assessment prioritises the risks using a pre-defined rating scale or qualifier (Rausand, 2011). The use of a risk matrix or probability impact graph that defines risks by the same set of triplets, probability, consequence, and sometimes exposure frequency (Duijm, 2015), Figure 4, is widely advocated (Cresswell, 2013).

Risk		Consequence				
Likelyhood		Minor	Medium	Major	Critical	Extreme
		1	2	3	4	5
Certain	5	5	10	15	20	25
Likely	4	4	8	12	16	20
Possible	3	3	6	9	12	15
Unlikely	2	2	4	6	8	10
Rare	1	1	2	3	4	5

Figure 4: Typical Probability Impact Graph

2.6 Causation of crowd incidents: proximate and distal

The first step in the risk management process is the identification of risks. To answer the question of what can go wrong, we need to understand the causality of crowd related incidents. This understanding is the foundation of crowd risk management and the development of recommendations for crowd safety (Rooney and Vanden Heuvel, 2004).

As with any event (Lyon, 1967), nearly always many contributing factors are involved in the causal chain (Still, 2000; Challenger, 2011) and can contain both (1) distal, or root, and (2) proximate causes (Lyon, 1967). Both Still (2014a) and Pin et al. (2011) endorse this for the context of crowds.

Proximate causality is the action or event immediately responsible for causing the incident; the most direct, effective or substantial cause, and can be either external or internal (Still, 2014a). Engineering flaws, terror, fire and natural disaster are external proximate causalities. Situations such as trips, slips and falls can be considered internal proximate causalities (Still, 2014a).

Root Causality is the fundamental, initiating and deeper underlying cause that management can control and allows for the generation of preventive measures. (Rooney and Vanden Heuvel, 2004; Still, 2014a). According to Williams (2001), the simplest way to determine the root cause is to “ask why” five times. Appendix C contains an example.

2.7 Proximate Causality of Death and Serious Injury

2.7.1 Proximate causality of crowd related incidents

Literature provides a series of studies that review a wide range of crowded events and crowd related incidents; see Appendix D for an overview. These studies indicate that (1) the forces in the crowd and (2) high density, leading to compressive asphyxia or crush, are the primary proximate causes injury and death during mass gatherings and events. Van de Sande (2013) shares this opinion, and the events in Davis and Associates' (2003) list of matters leading to crowd injury and death on outdoor music events, Table 2, all embed the notion of (high) crowd density and forces within the crowd. Alternatively, as Fruin (1993:1) puts it, 'it is the combination of inadequate facilities and deficient crowd management that result in injury and death'.

Davis & Associates' list of Events that led to injury and death:
• Slips, trips and falls in a crowded area.
• Fast, uncontrolled movement of large numbers of people, e.g. crowd rush,
• Crowd surges (slower than fast, uncontrolled crowd movement).
• Crushing against immovable objects, e.g. doors, barriers, fencing.
• Crushing against an immovable object, which subsequently breaks under the force, leading to a collapse of the front of the crowd.
• Pressure and crushing (human against human) caused by gross over-crowding.
• Opposing movements of people, e.g. ingress vs egress, causing crushing.

Table 2: the list of events that led to injury and death, taken from Davis & Associates (2003)

2.7.2 Crowd Density

Crowd density can be expressed as the number of persons in measured space (Drintewater and Gudjonson, 1989; Gwynne and Boyce, 2016) and is determined by the availability of space between crowd users as opposed to the total number of users (Kendrick, 2013). Although Fruin (1987) defines density in the same way, he chooses to use the inverse of density, the Pedestrian Area Module (PAM), expressed as the available area per person. Predtechenskii and Milinskii (1978) propose a third way based on the percentage of the area occupied by people (Hoskins, 2011), this dimensionless density (Schadschneider et al., 2018) is a quantity also known as occupancy (Schadschneider et al., 2012). The PAM and occupancy way of expressing crowd density has proven to be difficult to visualise and comprehend (Still, 2014a).

The number of persons in measured space to express density is most commonly used (Still, 2014a; Gwynne and Boyce, 2016). However, in times of COVID-19, with physical distancing measures implying a minimal distance between individuals, the assignment of a certain area per person brings Fruin's PAM back to the foreground (ESI, 2020; Mumford et al., 2020; SGSA, 2020; Team Event Safety Institute en CrowdProfessionals, 2020).

Crowd density relates not only to the size of the crowd but also to the design of the occupied area and a moment in time, and must be considered separately for static or moving (dynamic) crowds as they each have their limits (Fruin, 1987; Still, 2014a). Effects of (high)density are not only physical, as in dense crowds people are forced to enter each other's personal or even intimate zone (Hall, 1974).

For static crowds, the upper safety limit is set to five people per square meter (Still, 2014a; Sports Grounds Safety Authority, 2018); from six people per square meter, shockwaves are possible (Still, 2014a). Fruin (1993) and Raineri (2005, 2015) place this tipping point, where occupancy is 100%, at seven people per square meter. Although crowds rarely fill an area evenly (Still, 2000), crowd density is often expressed as an average (Hoskins, 2011; Still, 2019) and does not take into account that people come in all sizes (Still, 2000; Johansson et al., 2008; Gwynne and Boyce, 2016). Nevertheless, it is crucial to establish and consider the average person's space requirement (Weidmann, 1993). See Appendix E for details on the approach to body space.

Lee and Hughes (2006) define two types of outcomes of high crowd density and high crowd pressure, each responsible for about half of crowd-related deaths:

1. Being trampled to death in a dense but moving crowd after a fall (Lee and Hughes, 2006; Helbing and Mukerji, 2012). Still (2000, 2014a), Davis (2003), and Helbing et al. (2005) stress the importance of the banal issue of a trip, slip or fall in a crowd.
2. High crowd density, where individual movement is impossible, and the human body is crushed (Lee and Hughes, 2006) into other bodies, or obstacles, or when exposed to shockwaves or crowd collapse.

Crowd density relates to the forces and pressure at play within a crowd (Pauls, 1984; Fruin, 1993). Li et al. (2020) agree with previous findings (Zhu et al., 2016; Li et al., 2018) and state that force and density relate linearly when static but exponential when dynamic. Forces can reach such levels that they cause flail chest leading to compressive asphyxia and death (Fruin, 1993; Kroll et al., 2017). Table 3 summarises the findings of 11 studies into the tolerable force applied on a human chest and illustrate that, as Fruin (1993) stated, acute fatal compressive asphyxia can be induced with a relatively small crowd (Fattal and Cattaneo, 1976; Pin et al., 2011; C. Wang et al., 2020; X. Li et al., 2020).

Research	Force KN	Force Kg	Details
Fruin (1993)	3.600	367	300 sec.
Smith and Lim (1995)	1.900	194	♂, 3,780 sec.
Cosio and Taylor (1992)	10.000	1.020	0.15 sec. Dynamic Force
Hopkins et al. (1993)	6.227 1.112	635 113	♂, death after 15 sec. ♂, death after 240 - 360 sec.
Evans & Hayden (1971)	0.623 0.800	63 82	♂, against 100mm wide flat bar ♂, when allowed to push back ♀, significantly less
Hopkins et al. (1993)	0.800	64-82	♂ and ♀
Raineri (2015) **Kemp et al. (2004)**	1.100	136	150-180 sec. Beyond 180 sec death may occur at any time
Lin et al. (2017)	2.066	211	300 sec.
Kroll et al. (2017)	2.550 ± 0.250 4.050 ± 0.320	260 ± 26 kg 413 ± 33 kg	♂, chest-applied distributed static force ♂, chest-applied distributed dynamic force
Wang et al. (2020)	.0.600 1.800	61 184	1.800 sec. 300 sec.

Table 3: Summary of research into force applied to the human chest.

2.7.3 Crowd Flow

Next to crowd density, the flow rate is a critical element (Still, 2000, 2014a; Johansson et al., 2008). In the classic flow equation derived from fluid dynamics, flow volume is obtained by multiplying average speed with average density (Fruin, 1971, 1987) showing crowd density and flow rate are related (Fruin, 1971, 1987; Still, 2000; Johansson et al., 2008). With higher

density, the number of interactions between people increases, leading to reduced walking speed (Polus et al., 1983; Smith, 1995; Stanton and Wanless, 1995). Crowd flow is often expressed as people per meter per minute. Still (2000) stresses that any more analogies with fluid dynamics should be avoided and that in acknowledgement of Sime (1985), crowd dynamics must consider human behaviour and the pedestrian profile (Polus et al., 1983; Fruin, 1987; Still, 2000).

In times of physical distancing, to reduce droplet transmission (Pica and Bouvier, 2012; Yu et al., 2014; Xiao et al., 2017; Kutter et al., 2018), not only does an individual require more space (Mumford et al., 2020) resulting in lower density, but also flow rate is affected and will decrease.

2.7.4 Level of Service: Fruin and Polus

To better understand and scale flow and density, both Fruin and Polus use the concept of Level of Service (LoS). LoS originates fromin traffic engineering (Fruin, 1987). It combines density and speed analysis (Still, 2000) with observations of crowd flow and behaviour (Polus et al., 1983) in a quantitative and qualitative scale for safety and comfort for both static and dynamic areas (Fruin, 1987). Fruin and Polus developed a LoS for (1) walkways based on observations made in an urban environment. Fruin further differentiates between (2) stairs and (3) static areas. Appendix F shows and compares, for reference, the LoS of both Fruin and Polus and a comparison between Fruins LoS for static areas and Oberhagemanss (2012) density scale. Earl (2008) complies with the views of Kemp, Hill and Upton (2004; Upton, 2004), stating that Fruin's concept of density calculation does not comply with the reality of events. Fruin (1987) and Still (2000) stress that different situations need different standards.

2.8 Root Causality: The characteristics of crowd safety

2.8.1 Different wording, the same conclusion

Pauls (1984), Fruin (1993), Berlonghi (1993), and Sime (1995) use different wording to define the same four characteristics of crowd safety (1) Design, (2) Information, (3) Management, and (4) Crowd Behaviour. This is supported by crowd incident reports, as shown in Appendix D (Table 27). These characteristics and the wording used are summarised in Figure 5 and

defining either (1) the root causality of serious crowd injury or fatality or (2) a possible contribution to crowd safety.

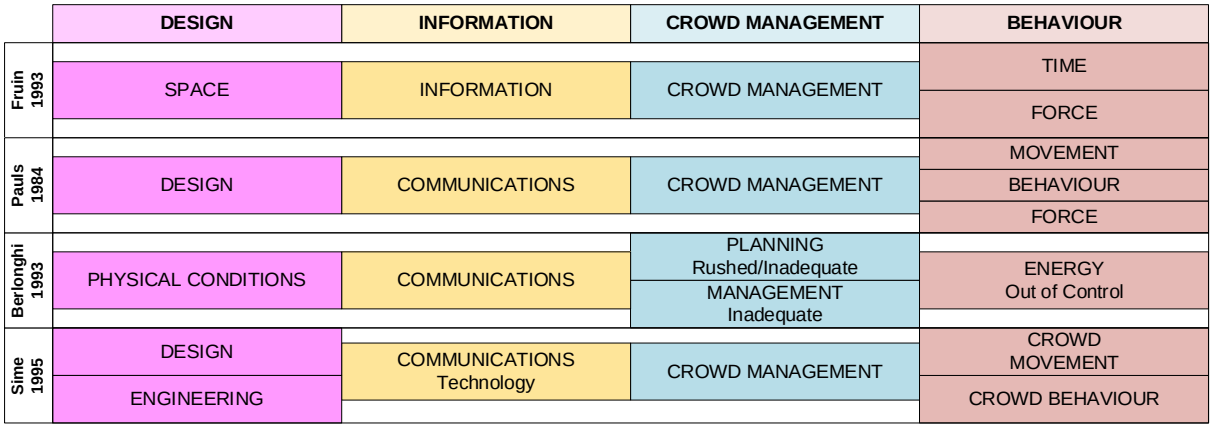


Figure 5: Crowd Safety Characteristics

Design

Fruin (1984, 1993) states that (venue) configuration, capacity and flow determine the level of crowding and defines ‘Space’ as one of the four primary elements in his ‘FIST’ model for understanding the causality of crowd incidents. Sime (1995), focussing on ingress and egress systems, refers to both Pauls (1984) and Fruin (1993) while he pleads for the integration of engineering and crowd psychology in the context of ‘Design’ and risk assessment. The design of the crowd’s physical environment should make the fit between people and buildings (Sime, 1985), and the considered dynamics of crowds must contain a behavioural element. They cannot be simplified to ‘the movement of ball-bearings through viscous fluids’ (Still, 2000:16).

Next to this, Berlonghi puts ‘physical condition’ on his list of seven general reasons why incidents occur at events. Pauls, Fruin, Berlonghi and Sime all refer to the relationship of occupants and their build environment as a root causality resulting in elements such as density, flow rates and capacity as essential proximate factors in crowd safety.

Information

Information as one of Fruin’s FIST elements embeds all means of information to steer r influence the crowd, including the training and actions of the crew (Fruin, 1993). So does Pauls (1984), as he refers to the 1971 Ibrox Park and 1979 Cincinnati crowd incidents and states that the crowd's lack of information played a significant role. In emphasising poor internal and

organisational communication, Berlonghi (1993) aligns with Fruin's (1993) Information factor. Unlike Sime (1995) and Fruin (1993), Berlonghi (1993) does not refer to communication with the crowd.

Crowd Management

When addressing crowd safety, Fruin (1993), Sime (1995) and Berlonghi (1993) mention the management of the crowd as an essential means to decrease crowd-related risks. In his discussion on movement and the two incidents in Ibrox Park and Cincinnati, Pauls (1984) recognises the need for crowd management and the involvement of poor crowd management in the incidents. So do Fruin (1993), Berlonghi (1993) and Sime (1995) while adding that preparation is key. Fruin (1993) takes it a step further and pleads for a certified Crowd Manager for venues with over 500 visitors.

Behaviour

Pauls (1984) argues the importance of human behaviour, whilst establishing a solid relationship between movement, the (building) design, flow rate and safety. Fruin (1993) acknowledges this with the elements of Force and Time. Force refers to the forces (1) within the crowd or (2) applied to the crowd due to the physical environment and movement. The aspect of 'Time' is embedded to capture different stages in an event or gathering and to denote the fact that forces can be accepted as a function of time, this is included in the qualitative scale of his Levels of Service (Fruin, 1971). Berlonghi (1993) does not directly refer to crowd behaviour but defines 'out of control energy' as a factor and herein includes excitement, frustration, anger… Later, Berlonghi (1995) refers directly to crowd behaviour when he defines different crowds. Sime (1995) refers to behaviour in a psychological and sociological manner and infers that crowds gather and move in the built environment.

2.8.2 DIM and ICE

Endorsing Fruin, Pauls, Sime and Berlonghi, Still (2014a) considers Design, Information and Management (DIM) as the three primary causality influences of crowd-related incidents and as the three ways how a crowd can be influenced, with Design as the most important factor (Still, 2009). Still (2009, 2014a) further argues that all events are composed of three phases (1)

Ingress, (2) Circulation, and (3) Egress, 'ICE'. Considering the DIM factors over the ICE event phases captures the dynamics of risk and the factor of 'Time' (Still, 2014a) as introduced by Fruin (1993). Figure 6 below shows the relationship between the DIM-ICE Model and the characteristics of Crowd Safety as defined by Fruin, Sime, Pauls and Berlonghi.

		ICE 'Time'				Time is captured in the ICE-axis of the DIM-ICE model the dynamics of risk both in time and place.
		INGRESS	**CIRCULATION**		**EGRESS**	
DIM	**DESIGN**	FORCE	FORCE/ MOVEMENT/ BEHAVIOUR	CROWD BEHAVIOUR MOVEMENT	ENERGY Out of Control	The concept of Force is a function of the crowd, crowd movement and (site) Design The notion of 'Space' Engineering, Design and physical conditiopns is further developed by Still into the broad concept of (site) Design in the DIM-ICE Model.
		SPACE	DESIGN	DESIGN & Engineering	PHYSICAL CONDITIONS Unsafe	
	INFORMATION	INFORMATION	COMMUNICATIONS	COMMUNICATIONS Technology	COMMUNICATIONS Poor	The "Information" in FIST correlates one on one with the "Information" parameter in DIM. So does the need for internal and external communications as mentionned by Sime, Pauls and Berlonghi.
	MANAGEMENT	CROWD MANAGEMENT	CROWD MANAGEMENT	CROWD MANAGEMENT	MANAGEMENT PLANNING Inadequate	One of Fruin's main conclusions is that (crowd) management is necessary to prevent crowd disasters. Still embedds management as a concept in the DIM-ICE model.
		Fruin	Pauls	Sime	Berlonghi	

Figure 6: The DIM-ICE model captures the characteristics of Crowd Safety

Alternatively, the Sports Ground Safety Authority (2015) identifies five event phases (1) Arrival, (2) Ingress, (3) Movement, (4) Egress and (5) Dispersal, AIMED. Considering "Movement", the equal counterpart of 'Circulation', three of the five phases are identical to ICE. With the London 2012 Olympics, the focus was on the additional step, the 'Last mile' (Sports Grounds Safety Authority, 2016), leading to the ALIMED or ALICED model. This addition, 'Arrival' and 'Last mile' before actual Ingress, and the additional 'Dispersal' suggest that the model embeds dynamics and movement both over time and in space. One model should not combine dynamics, risk elements and movement (Still, 2016). The Event Safety Alliance (2020) produced an ANSI standard for crowd management and added expectation as a factor, resulting in the DIME-ICE model. This element of 'Expectation' should be embedded in the DIM characteristics and the RAMP-Analysis.

2.9 The Static Personal Area Module within the Context of Physical Distancing

The concept of physical distancing translates into density (Mumford et al., 2020) and thus determines both the capacity and the flow rate of a passageway (Fruin, 1971; Still, 2000; Oberhagemann, 2012). The Personal Area Module, dictated by the physical distancing norm (D), can be approached and calculated in different ways (Mumford et al., 2020; SGSA, 2020).

2.9.1 Nose to Nose

This first method is based on the distance from the centre point from one body to the other body's centre point (Mumford et al., 2020; SGSA, 2020). The required area can be represented as:

1. a square (Fruin, 1987; Still, 2000; Oberhagemann, 2012) with side D;
2. a circle (INCONTROL Simulation Solutions, 2020; Mumford et al., 2020; Poeteren, 2020; Thunderhead Engineering, 2020) with radius D;
3. or the circumscribed hexagon of the circle with radius D (Mumford et al., 2020),

Figure 7 illustrates the square, circle and hexagon representation and Table 4 summarises the PAM, Density and Ratio for each representation with a distancing norm of 1.5 meters.

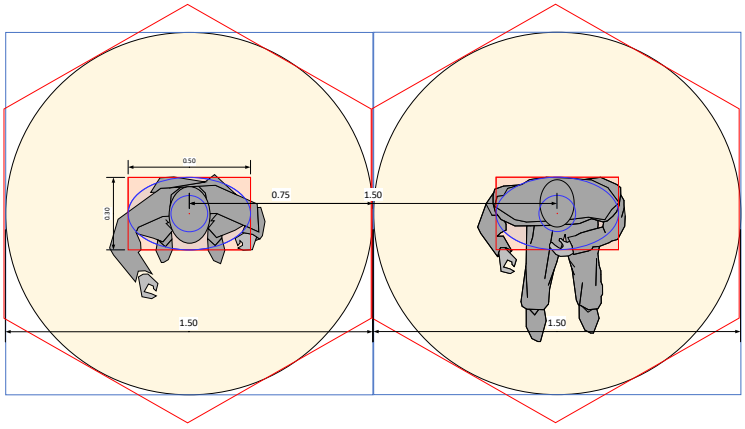


Figure 7: Representation of the PAM with 1.5 m distancing – nose to nose/static

D = 1.50	PAM (m^2/p)	Density (p/m^2)	Occupancy Ratio*
Circle	1.77	0.57	8.49%
Square	2.25	0.44	7.70%
Hexagon	1.95	0.51	6.67%
* for the occupancy a square body projection (Dridi, 2015) of 0.5 m by 0.3 meters (Weidmann, 1993; Still, 2000) is assumed			

Table 4: PAM, Density and Occupancy with 1.5 m Distancing – nose to nose

Despite not resulting in the most space per individual (Steinhaus, 1983), the hexagon representation, which forms the Voronoi tiling, fills the space most efficiently (Hales, 2000; Mumford et al., 2020), as shown in Figure 8. However, for capacity calculations, both Mumford et al. (2020) and SGSA (2020) suggest using the square PAM.

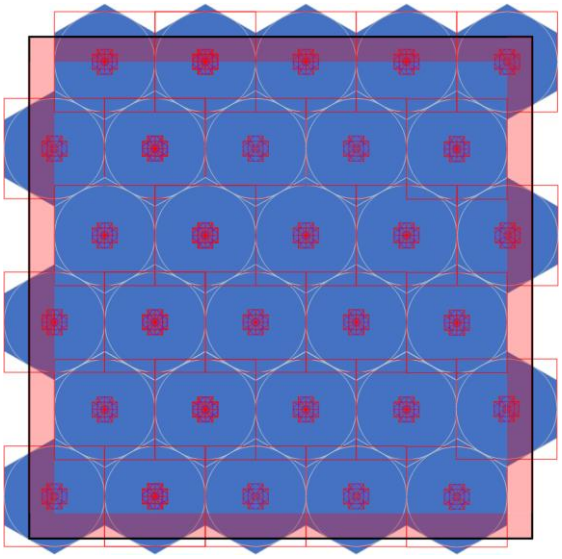


Figure 8: Tessellation of squares, circles, and hexagons

2.9.2 Body projection

The second method considers the body projection and measures distancing from body to body (SGSA, 2020). Establishing an average value for the body ellipse is the first thing to do, considering that people come in all shapes and sizes (Still, 2000; Johansson et al., 2008; Gwynne and Boyce, 2016). Different values have been assigned to the average person's space requirement; see Appendix E for details.

Applying the body projection method for static zones, sitting or standing, and the Still (2000) and Weidmann (1993) values result in a PAM as shown in Figure 9. Table 5 summarises the PAM, Density and Ratio for each representation with a distancing norm of 1.5 meters.

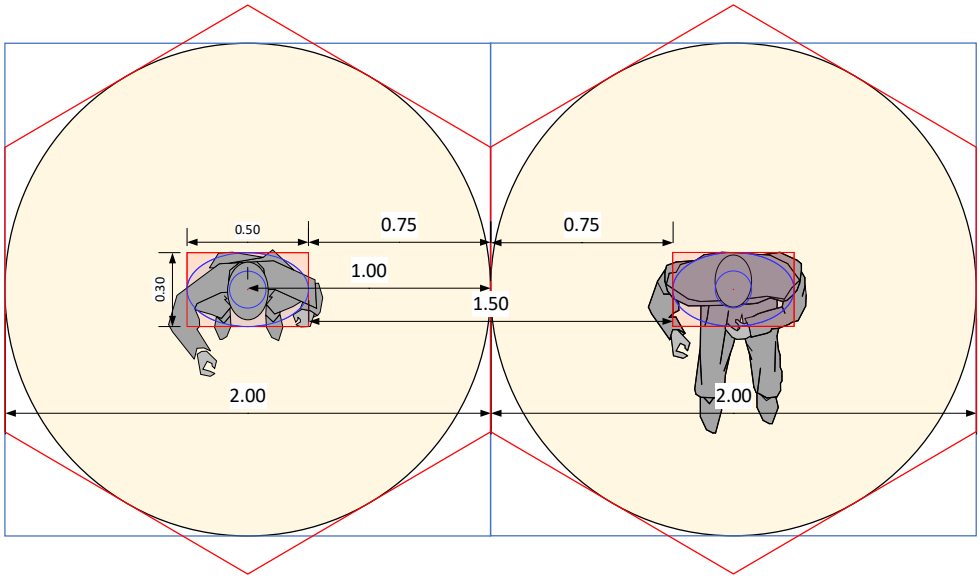


Figure 9: Representation of the PAM with 1.5 m distancing – body to body/static

D = 1.50	PAM (m²/p)	Density (p/m²)	Occupancy Ratio*
Circle	3.14	0.32	4.77%
Square	4.00	0.25	3.75%
Hexagon	3.46	0.29	4.33%
* for the occupancy a square body projection (Dridi, 2015) of 0.5 m by 0.3 meters (Weidmann, 1993; Still, 2000) is assumed			

Table 5: PAM, Density and Occupancy with 1.5 m Distancing – body to body

2.10 The Dynamic Personal Area Module within the context of physical distancing

2.10.1 Nose to nose

The SGSA (2020) withholds the same values for dynamic as for static areas, as shown in Table 4, illustrated in Figure 10. Mumford et al. (2020) approach the dynamic zones with the idea that dynamics and movement need more space per person, as Fruin (1971), Polus et al. (1983), and Still (2000, 2014a) suggest.

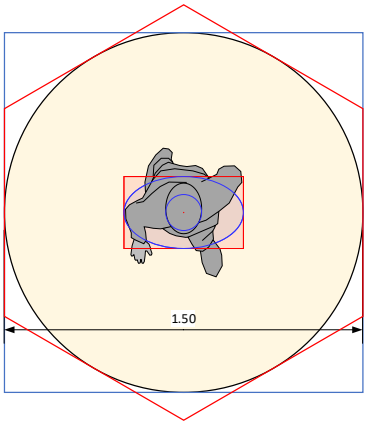


Figure 10: Representation of the PAM with 1.5 m distancing – nose to nose/Dynamic – SGSA

The method considers an inner 'movement' area with a radius equal to the multiplication of (1) walking speed and (2) stop time (the x value). Figure 11 illustrates this. This movement area is enlarged with half the distancing norm, the total radius is thus [(walking speed x stop-time) + ½ Distancing], the calculation (see equation 1) calculates the circular PAM and adjusts this to the area of the circumscribed rectangle. Considering this composite radius, the hexagonal PAM can be calculated. The values are summarized in Table 6; the x values are taken from Mumford et al. (2020) for three situations.

$$PAM = \frac{\pi(x + 1/2D)^2}{0.9069} m^2 \ \ with \ \ x = walkingspeed * stoptime$$

Equation 1: Calculation of required (square) dynamic space from Mumford et al. (2020)

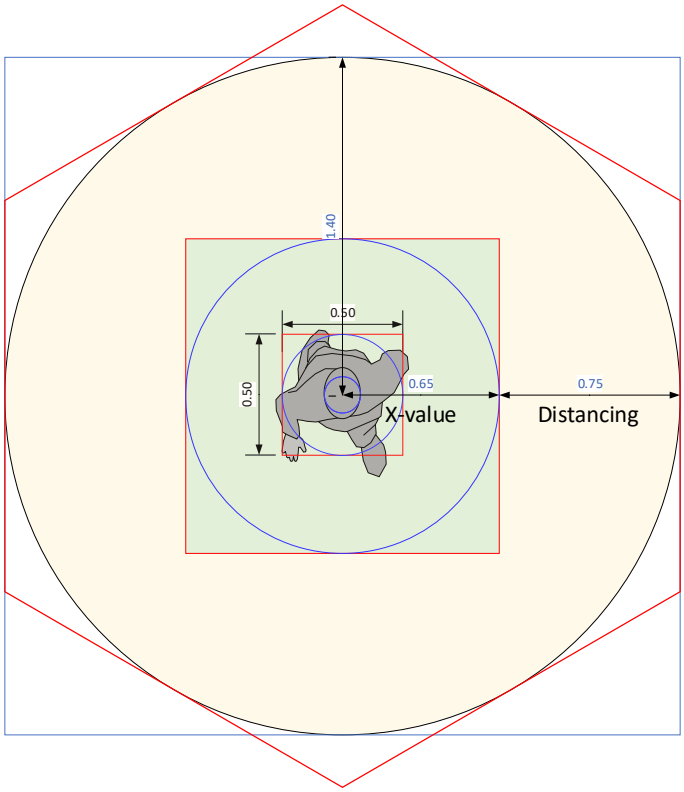


Figure 11: PAM for Dynamic 'Retail' areas as proposed by Mumford et al. (2020)

D = 1.50	Retail < 500m²			Retail or managed commercial space > 500 m²			Public urban space		
	PAM (m²/p)	Density (p/m²)	Occup. Ratio*	PAM (m²/p)	Density (p/m²)	Occup. Ratio	PAM (m²/p)	Density (p/m²)	Occup. Ratio
Circle	6.16	0.16	2.44%	6.88	0.15	2.18%	7.40	0.14	2.03%
Square	7.84	0.13	1.91%	8.76	0.11	1.71%	9.42	0.11	1.59%
Hexagon	6.79	0.15	2.21%	7.59	0.13	1.98%	8.16	0.12	1.84%
* for the occupancy a square body projection (Dridi, 2015) of 0.5 m by 0.3 meters (Weidmann, 1993; Still, 2000) is assumed									

Table 6: PAM for Dynamic areas as proposed by Mumford et al. (2020)

2.10.2 Body Projection

When considering body size, the SGSA (2020) considers a body projection of 0.6 m by 0.6 m (Figure 12). Table 7 summarises the PAM, Density and Ratio for each representation with a distancing norm of 1.5 meters.

D = 1.50	PAM (m²/p)	Density (p/m²)	Occupancy Ratio*
Circle	3.46	0.29	4.33%
Square	4.41	0.23	3.40%
Hexagon	3.82	0.26	3.93%
* for the occupancy a square body projection (Dridi, 2015) of 0.5 m by 0.3 meters (Weidmann, 1993; Still, 2000) is assumed			

Table 7: PAM, Density and Occupancy with 1.5 m Distancing – body to body - SGSA

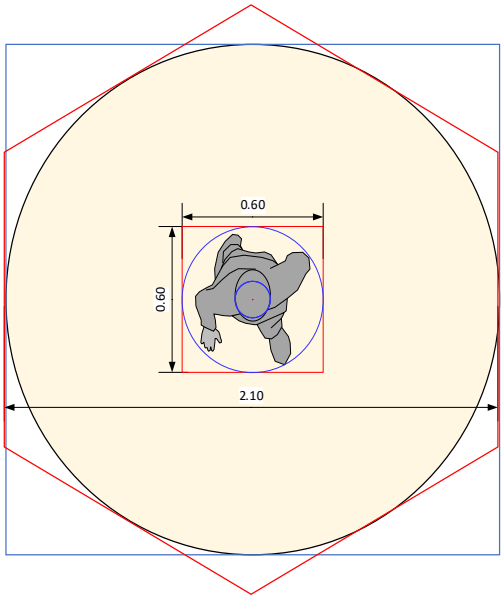


Figure 12: 'no-touch' - PAM for Dynamic areas - SGSA

When body size, as proposed by Weidman (1993) and Still (2000), is embedded in equation 1, the PAM can be calculated in line with the method as presented by Mumford et al. (2020), see equation 2. Table 8 summarizes the PAM, Density and Ratio for each representation with a distancing norm of 1.5 meters. Figure 13 shows an example;

$$PAM = \frac{\pi\left(x + (\frac{1}{2} \times 0.50) + 1/2D\right)^2}{0.9069} m^2 \ \ with \ \ x = walkingspeed * stoptime$$

Equation 2: Calculation of required (square) dynamic space with consideration of body width and D = 1.5m adapted from Mumford et al. (2020)

D = 1.50	Retail < 500m²			Retail or managed commercial space > 500 m²			Public urban space		
	PAM (m²/p)	Density (p/m²)	Occup. Ratio*	PAM (m²/p)	Density (p/m²)	Occup. Ratio	PAM (m²/p)	Density (p/m²)	Occup. Ratio
Circle	8.55	0.12	1.75%	9.40	0.11	1.60%	10.01	0.10	1.50%
Square	10.89	0.09	1.38%	11.97	0.08	1.25%	12.74	0.08	1.18%
Hexagon	9.43	0.11	1.59%	10.37	0.10	1.45%	11.04	0.09	1.36%
* for the occupancy a square body projection (Dridi, 2015) of 0.5 m by 0.3 meters (Weidmann, 1993; Still, 2000) is assumed									

Table 8: PAM for Dynamic areas proposed by Mumford et al. (2020) with embedded body projection.

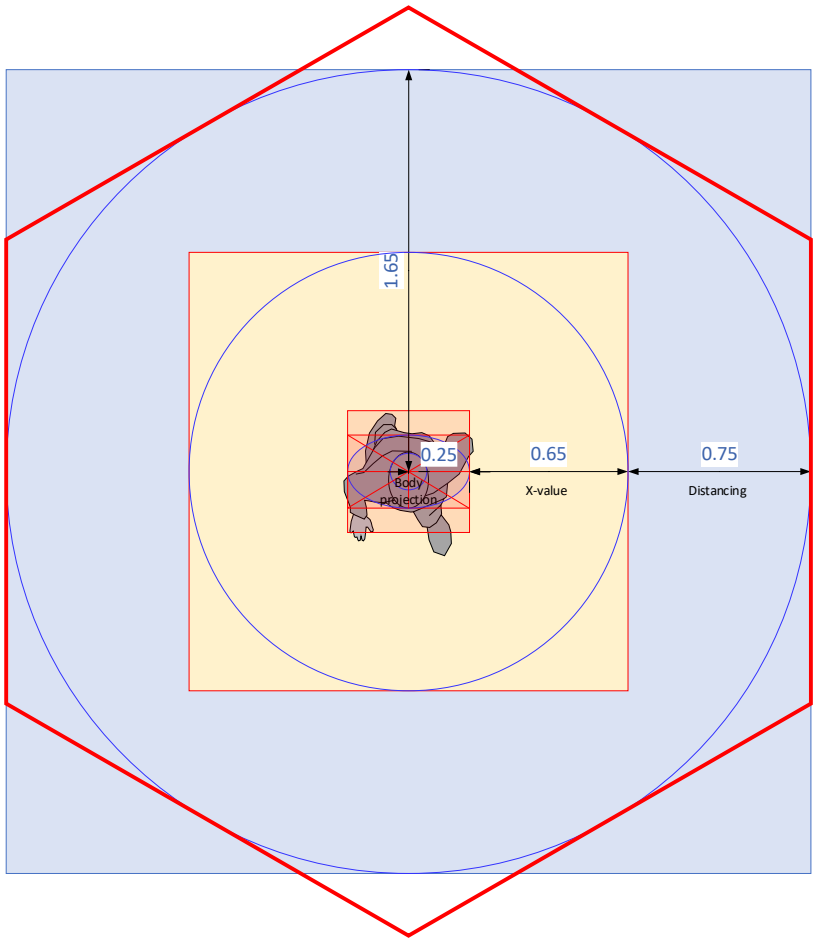


Figure 13: 'body to body'' - PAM for Dynamic areas

2.11 Crowd Science Tools for Crowd and Event Modelling

Models are composed with the singlular determining aspects and break down a complex (process) event in a series of parts (Still, 2014a). Tthe modelling process assists in understanding, visualising, and communicating critical crowd dynamic elements to all stakeholders (Still, 2014a) and helps the modeller to gain insight into both the root (Design, Information, Management) and proximate causalities of crowd incidents (Density, Flow, Force). Tools can be (1) a theoretical framework, (2) a method, a way of doing things, procedures, an equation…, and (3) technical or software solutions (Safe Project, 2021). Literature provides a series of tools that can be used to model crowds.

2.11.1 The DIM ICE Model

The DIM-ICE Metamodel provides a framework for collecting and displaying information so that the details highlight the unique features of the event and the site characteristics. The DIM-

ICE Model combines Ingress, Circulation and Egress and the three primary causality influences Design, Information and Management in a matrix, a systematic checklist for risk assessment and crowd management (Still, 2014a). On an ordinal scale, Colour codes prioritise low and high-risk items or areas to further research (Still, 2014a, 2014b).

2.11.2 RAMP Analysis

RAMP analysis provides insight into the relationship between site design, human behaviour and ICE and outlines (1) Routes – directions and flow paths, (2) Areas- effective area and whether an area holds static crowds or is more dynamic, (3) Movement – flow rates, congestion or queueing and fill times, (4) Profile – visitor profile, expectations and likely behaviour (Still, 2014a).

2.11.3 Risk and Congestion Mapping

Risk and congestion mapping comprises the mapping and highlighting of density or risk zones over time. The result is a visual representation of the severity, location, time, and risk dynamic (Still, 2014b), providing insights and enabling communication easiness of a complex idea to stakeholders (Still, 2014a).

2.11.4 Graph Theory

Components of Graph Theory can document and analyse all the relevant parts of the system or customer journey (Still, 2000, 2014a). The Event Network Graph visually links all facilities and processes as vertices and edges (Trudeau, 1994). The output of one vertex is the input of the other, and interaction is described (Kang and Choi, 2010). The Event Netwerk Graph finds its origin in the Flow Diagram as introduced by Tocher (1960).

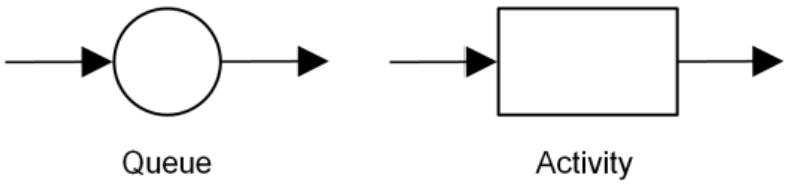


Figure 14 - Activity Cycle Diagram Objects (Kang and Choi, 2010)

Within the diagram, an entity travels from one server to the next and alternates between getting served and waiting to be served (Kang and Choi, 2010). Circles show queueing; rectangles

show activity, as shown in Figure 14. The whole system can be modelled using these two symbols and connecting them with arcs.

2.11.5 Basis Flow Equation

Fruin (1987) proposes the equation for Pedestrian Flow volume, derived from fluid dynamics to calculate Pedestrian Flow, Speed, and Density or the Pedestrian Area Module as Fruin used.

$$Pedestrian\ Flow\ Volume = Speed\ x\ Density$$

Equation 3: Pedestrian Flow Volume (Density)

OR

$$Pedestrian\ Flow\ Volume = \frac{Speed}{Persnoal\ Area\ Module}$$

Equation 4: Pedestrian Flow Volume (PAM)

2.11.6 Queue Analysis

Crowd congestion at places of public assembly or events can often be brought back to queueing systems, either at entries, turnstiles, ticket machines, food and beverage points or any other place where people need to wait for a particular service. Queue Theory originatesfrom the research on telecommunication traffic by mathematician, statistician and engineer Agner Krarup Erlang (Krarup, 2004; Still, 2016a). These accurate calculations rely on decent primary data. In crowd safety, this kind of data is seldom available and influenced by many external sources. Even more, human behaviour itself comes with a significant degree of uncertainty (Still, 2014a, 2016a). Therefore, Erlang's mathematical queueing formulae are not likely suited for application within the field of crowd safety (Still, 2016a).

The most crowd safety-related queueing systems can be reduced to the M/M/1 model (Kendall, 1953) with the assumption that there is a single queue, and both the Arrival rate and the Service Rate are Markovian, respectively a Poisson probability distribution and a negative exponential distribution (Still, 2016a). The queue discipline is likely to be “First Come, First Served” (Still, 2016a). The simpler formula, N=T(A-D), a simplification of the single queue single server

model, allows for a quick and easy calculation of the queue build up over time and is functional in almost any crowd related case (Still, 2016a), see Figure 15 and table below.

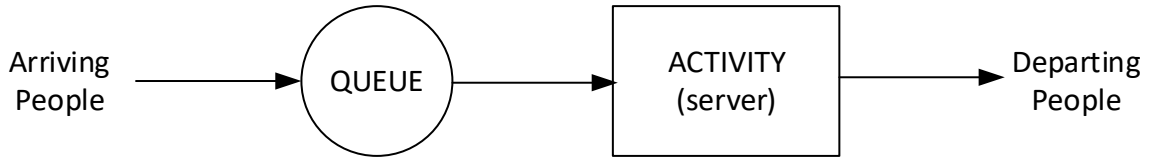


Figure 15: Waiting line components.

$$N = T(A - D)$$

Equation 5: Simple Queueing Formula

Symbol	Meaning
N	the number of people in queue
T	the number of time units,
A	the Arrival per time unit (ʎ)
D	the Departure per unit of time (μ).

Table 9: Simple Queueing Formula

The results are considered when applying RAMP analysis, using the DIM ICE Model and assessing risks, whether on a congestion map or any other risk analysis methodology.

2.11.7 Crowd Psychology

Reicher (2011) differentiates between (1) physical crowds and (2) psychological crowds. A fundamental difference is that psychological crowds share a social identity. In case of emergency, often physical crowds transform into psychological (Reicher, 2011). It is critical, though, that those imposing rules are seen as ingroup; this can be achieved by early and correct communication and proper explanation of why rules are implied and why they affect us all (Elcheroth and Drury, 2020).

2.11.8 Crowd Flow Simulation

Numerous crowd simulation software solutions are available on the market (Kuligowski and Gwynne, 2005; Still, 2007; Kuligowski et al., 2010; Duives et al., 2013; Ronchi et al., 2020). Historically, crowd simulation tools were developed to demonstrate that buildings' design concepts were safe and that occupants could leave efficiently (Gwynne et al., 1999; Kuligowski and Peacock, 2005). Now the scope of this performance-based tool has been broadened to the field of (1) spatial analysis, (2) level of service, (3) evacuation strategies, (4) evacuation

route planning, (5) communication, (6) system failure, and (7) sensitivity analysis, see Table 10 for details. To understand the differences and peculiarities of these simulation tools, it is essential to understand the basics of each tool's underlying techniques and methods (Still, 2007, 2014a; Kuligowski et al., 2010; Duives et al., 2013).

Field	Details	Source
Spatial analysis	simulate how crowds use their environment	(Challenger et al., 2010a, 2010b; Still, 2014a)
Level of Service	determine levels of comfort, safety, and security for crowds	(Agraa and Whitehead, 1968; Lovas, 1994; Farenc et al., 2000; Challenger et al., 2010a, 2010b)
Evacuation strategy	prepare and evaluate large-scale evacuation processes: • in general • in event-related situations • urban environments and stadia	(Still, 2000; Fell, 2003) (Almeida et al., 2016; Ronchi and Nilsson, 2016; Ronchi et al., 2016), (Alvarez et al., 2016) (Klüpfel et al., 2003; Klüpfel, 2007; Zarket et al., 2014)
Evacuation routes	• the level of probability of use of escape routes • bottlenecks • the level of crowd safety	(Kuligowski and Peacock, 2005; Kuligowski et al., 2010)
Communication	produce visual output, easing communication on dynamic crowd behaviour	(Challenger et al., 2010a, 2010b)
System failure	test when and where a system or network will fail	(Challenger et al., 2010a, 2010b; Still, 2014a)
Sensitivity analysis	research in detail specific phenomena using the quantitative and more objective methodology of sensitivity analysis, this explicit method requires less human analysis.	(Harding et al., 2010)

Table 10: Simulation: fields of use

2.12 In summary

The findings of the literature review can be summarised as:

- The transmission of the SARS-CoV-2 respiratory virus, responsible for COVID-19, between people shows the same characteristics as other respiratory viruses and are transmitted via droplets, fomites and aerosols.
- To stop the pandemic, the transfer of the virus must be decreased in order for the reproductive number to drop.
- Risk assessment in time of pandemic must embed the risk of virus transmission.
- Crowds can be managed during emergency as panic is not a common response in case of emergency.
- A pandemic can be considered a common faith transforming the physical crowd into a psychological crowd.
- The pandemic induced shared social identity must be nurtured to succeed with non-pharmaceutical interventions of hygiene, face masks and distancing.
- Non-pharmaceutical interventions are behavioural interventions. Distancing and the management of interaction between people can be considered crowd management.
- Crowd management embeds (1) the element of preparation, (2) the element of management, (3) the distinction between static and dynamic areas, (4) a link with design, (5) the importance of human behaviour and psychology, and (6) the intention of managing risk.
- Crowd safety is to be seen in the broader aspect of risk management, and the ISO risk management process can be used in the context of mass gathering situations.
- Risk analysis is the core of the safety and security plan during pandemic, disease, or transfer related risks need to be addressed without neglecting other risks like terror.
- Six prominent authors (Fruin, Pauls, Berlonghi, Sime, Still, and Drury) with backgrounds in both psychology and engineering all agree on the main characteristics of crowd safety. Design, Information and Management play a vital role in the root

causality of many crowd incidents, whilst the elements of density, flow and force are the main proximate contributors to injury and fatality.

- A series of crowd model and management tools are developed to tackle these causational characteristics on both the root and proximate level.
- There is a clear link between physical distancing, density, capacity and flow.
- There are different ways of representing and calculating the PAM.

3 Methodology

3.1 Framework

This Methodology chapter reflects on and provides justification for the different steps and assumptions in the data collection process in this dissertation (Bryman, 2016; Kumar, 2018) and is the result of peeling the research 'onion' as suggested by Saunders et al. (2016) as shown in Figure 16. Saunders et al. (2016) distinguish five outer layers embracing the core of actual data collection and analysis. Each of these layers (1) Research Philosophy, (2) Approach to theory development, (3) Methodology, (4) Research Strategy and (5) Time Horizon is peeled away in the following chapters.

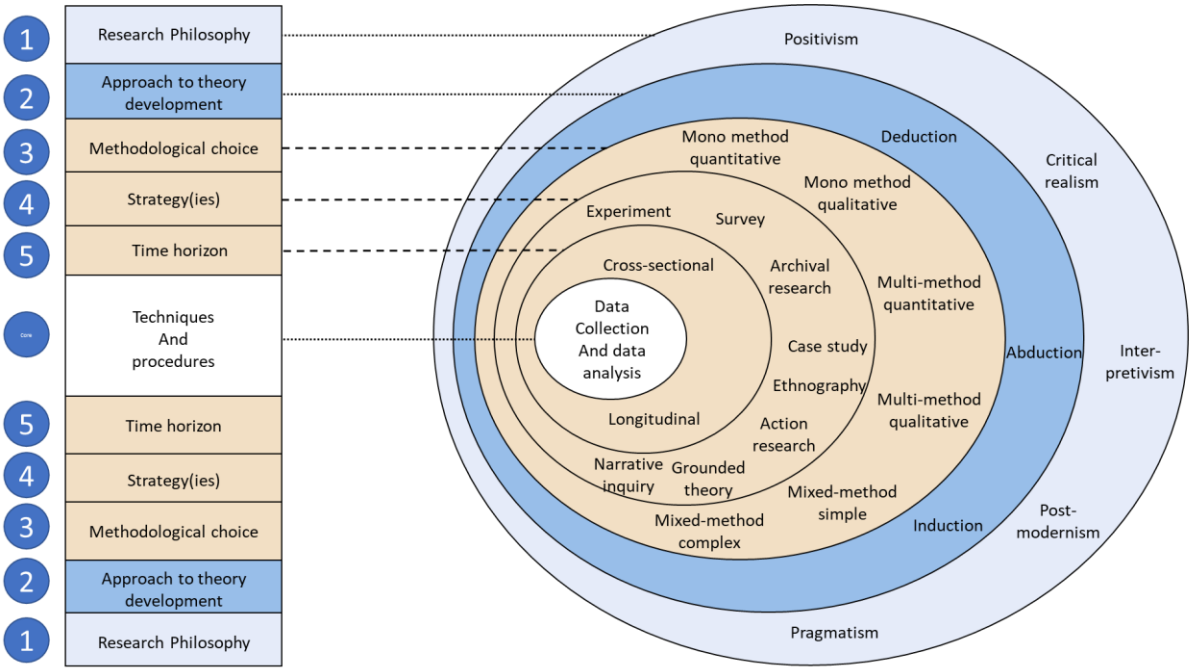


Figure 16 - The Research Onion adapted from Saunders et al. 2016

3.1.1 Research Philosophy

The first layer, the Research Philosophy layer, reflects on the data collection method to answer the research questions (Saunders et al., 2016) as set in chapter 1. Saunders et al. (2016) consider five philosophic stances, each characterized by a difference in the base assumptions. Wisker (2008) distinguishes (1) ontology, (2) epistemology as the basic philosophical assumptions.

Ontology explores the nature and structure of reality, and can be defined as the study of being (Ahmed, 2008), and answers the fundamental philosophical question of ‘what is there?’ (Scales, 2013). Ontology holds two positions (Scales, 2013), first, objectivism that denies the dependency of meanings on the social actors, and, second constructionism that not only differentiates between reality and perceived reality but also learns how human behaviour is impacted by these differences (Wisker, 2008; AllAssignmentHelpUK, 2017).

Epistemology answers the next fundamental philosophical question of ‘How do you know what is there?’ (Scales, 2013). Furthermore, it relates to scientific research principles and methodology (Wisker, 2008). Here, epistemology touches the (1) positivism paradigm that the natural world is subject to fixed laws, (2) the interpretivism paradigm that states knowledge of the social world influences human behaviour (Wisker, 2008; Winstanley, 2010; Scales, 2013), and (3) the Pragmatism paradigm that knowledge and theories in specific contexts enable successful problem solving (Kelemen and Rumens, 2008; Saunders et al., 2016).

For this study, the constructionist, interpretivism, and pragmatic assumptions were made that the perceived reality of individuals or groups are the result of different meanings constructed with different interpretations and views and that theory and knowledge are only relevant when they support the desired outcome (Kelemen and Rumens, 2008).

3.1.2 Approach to Theory Development

Saunders et al. (2016) define three ways to theory development (1) deduction, (2) induction, and (3) abduction. This study used the inductive approach to assess operations and identify themes and patterns to create recommendations on a conceptual framework, as suggested by Saunders et al. (2016)

3.1.3 Research Methodology

In the methodological layer of the research ‘onion’, two complementary and supportive options are present, quantitative research and qualitative research (Baker and Foy, 2008; Biggam, 2017). Figure 17 shows how both methods can be used alone or in combination.

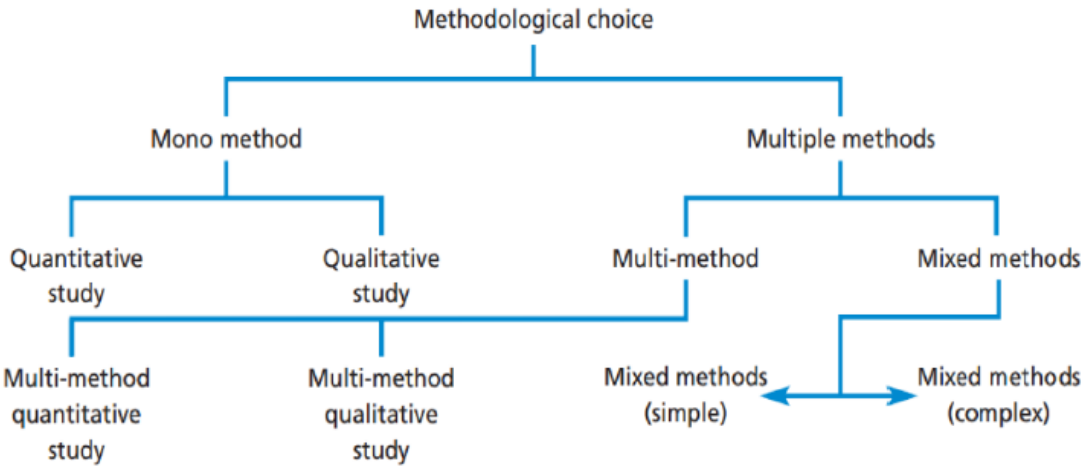


Figure 17: Methodological choices, taken from Saunders et al. (2016)

Quantitative research often involves existing theories or hypotheses of which different variables are measured and questioned; qualitative research aims at meanings, believes and experiences (Wisker, 2008). This study's research objectives were oriented towards understanding the ‘how’ and ‘why’ and were not suited for a quantitative approach (Wisker, 2008); therefore, a Mono method qualitative approach was chosen for this research.

3.1.4 Research Strategy

Saunders et al. (2016) and Denscombe (2014) list different research strategies, summarized in table 11. In a phenomenological strategy (Denscombe, 2014; Biggam, 2017) and after analysis of the present body of literature, industry experts' experience was sought through a narrative inquiry (Saunders et al., 2016) to meet the research objectives. This because of the lack of primary data and the assumption that expert knowledge and experience in the use of crowd management tools in the context of COVID-19 could help with research objective 4 and 5.

Strategy	Source	Purpose
Surveys and sampling	S/D	• measure some aspect of a social phenomenon or trend • gather facts in order to test a theory
Case studies	S/D	• understand the complex relationship between factors as they operate within a particular social setting
Experiments	S/D	• identify the cause of something • observe the influence of specific factors
Ethnography	S/D	• describe cultural practices and traditions • interpret social interactions within a culture
Phenomenology	D	• describe the essence of specific types of personal experience • understand things through the eyes of someone else
Grounded theory	S/D	• clarify concepts or produce new theories • explore a new topic and provide new insights
Action research	S/D	• solve a practical problem • produce guidelines for best practice
Systematic reviews	D	• get an objective overview of evidence on a specific topic • evaluate the effectiveness of projects or interventions
Mixed methods	D	• evaluate a new policy and gauge its impact • compare alternative perspectives on a phenomenon • combine aspects of the other strategies
Narrative Inquiry	S	• a personal account which interprets an event or sequence of events • the researcher believes that the experiences of his participants can best be accessed by collecting and analysing these as stories
Archival and Document research	S	• An archival research strategy uses administrative records and documents as the main source of data
Sources: S = Saunders et al. 2016 / D = Denscombe 2014		

Table 11: Research strategies by Denscombe (2014) and Saunders (2016)

There are three main methods of narrative inquiry (1) structured, (2) semi-structured, and (3) unstructured interviews (Wisker, 2008; Winstanley, 2010; Saunders et al., 2016). Each method's advantages and disadvantages are summarised in Table 12, taken from Winstanley (2010). When the goal is to determine people's perspective and experience, the semi-structured interview is most common within the qualitative methodology (Arksey and Knight, 1999) despite the disadvantages, as shown in Table 12. The semi-structured interview has fixed main questions, and the script is fixed, but follow-up questions can be used to go more in-depth of the answers and explore topics that emerge during the interview (Arksey and Knight, 1999).

Structured	Semi structured	Unstructured
Uses direct and specific questions	Some key questions planned, with allowance for other issues to be raised	Free-flowing discussion; no fixed agenda
Specific order of questions	Indicative order of questions, but okay to depart from the order	No specific order for questions
The focus is on how many people make the same points rather than individual views.	Supplementary questions are offered to collate people's different viewpoints, but all are expected to answer the main question.	The interviewer is seeking depth of response and follows the interests of the interviewee
Must follow fixed schedule	Can leave out some questions as appropriate	Difficult to replicate as follows interests of interviewee will differ from person to person
Rather rigid style	Relaxed style	Conversational

Table 12: Features of Different Kinds of Interviews taken from Winstanley (2010)

3.1.5 Time Horizon

Further peeling Saunders et al.'s (2016) research onion takes the methodology to the level of time horizon. A distinction is made between longitudinal and cross-sectional research. This study caught the situation at a particular moment in time and is cross-sectional.

3.2 Data Collection – Secondary data

The study focussed on expert interviews to draw conclusions and make recommendations on the future strategy for coping with events and places of public assembly in the case of respiratory virus outbreaks.

First, the study established the connection between 'conventional' crowd science and crowd management tools and the implementation of physical distancing as a non-pharmaceutical intervention for respiratory viruses on events and at places of mass gathering. To achieve this, secondary data was researched in the literature review.

The literature review contains two main topics (1) SARS-CoV-2 and the non-pharmaceutical interventions, and (2) crowd safety and crowd management. Literature was searched using the MMU Library, Google Scholar, Google, the WHO Global research database on COVID-19, and the backwards snowball technique (Leary and Kershaw, 2014); see Table 13 for the initial search keywords. For the part on SARS-CoV-2, the literature review explored the virus and

disease's main characteristics before going into the non-pharmaceutical interventions linked to the ways of transmission. On the level of crowd management, the literature review narrowed down from the broad topic of crowd safety and the root causality of incidents to the proximate causes and the tools to manage crowds.

Topic	Search word
Crowd Safety	Risk Analysis
	Crowd Safety
	Crowd Incident
	Crowd Incident Causality
	Crowd Dynamics
	Crowd Density
	Crowd Management
	Crowd Psychology
	Crowd Management Tools
SARS-CoV-2	SARS-CoV-2
	SARS-CoV-2 Transmission
	SARS-CoV-2 Non-pharmaceutical Intervention
	Social distancing
	Physical distancing

Table 13: Literature review – initial search words

The literature search revealed a rich body of secondary data for both topics. Despite being a new virus, a vast body of research is already available on SARS-CoV-2, and many academic publishers made the resources on SARS-CoV-2 open access. For the part on crowd safety, six prominent authors, combined with a wealth of case-study-like publications on crowd incidents, lead to the essence of crowd safety. The combination of both topics revealed that despite conventional crowd safety methods and principles suited for the development and implementation of physical distance measurers, the ‘how-to’ or a plan of ‘approach’ is not readily available. The literature review laid the foundation of the semi-structured interviews' questions and setup (Marshall and Rossman, 2016).

3.3 Data Collection – Primary Data: Semi-structured interviews

3.3.1 Sample Strategy and Size

To meet the objectives, and given the subject, research philosophy and strategy, the study sought experts' experiences and insights (Saunders et al., 2016). Semi-structured interviews

were conducted with event and crowd safety professionals. Choosing a sample strategy is a strategic decision (Biggam, 2017); using the decision tree as drawn up by Saunders et al. (2016), a non-probability approach with purposive sampling was decided upon.

3.3.2 Sample Selection

The researcher has been working in the events security and safety industry since 2000 and possesses an international network of crowd safety professionals; this helps convince possible participants to participate in the study (Saunders et al., 2016). The respondents were chosen from this network based on predefined criteria.

Criterion 1: Expertise in crowd safety and safety management on events or at places of public assembly.

To become an expert, a person requires the 'equivalent of ten years of combined studies and related work experience' (Herling, 2000:15). Herling (2000:9) further defines expertise as 'the possession of superior skills or knowledge in a particular area of study'. In line with the vision of Meuser and Nagel (2009), the researcher decided whether a possible respondent is an expert or not.

Criterion 2: Experience in crowd safety and safety management of events or places of public assembly during the COVID-19 pandemic.

Wisker (2008) and Sounders et al. (2016) agree that there are no rules on the sample size. Saunders et al. (2016) further suggest a minimum sample size of 5-25 for semi-structured interviews in non-probability sampling. As most events have been cancelled since the start of the pandemic, the relatively small number of existing experts (criterion 1) was even further limited by criterion 2. Therefore, the sample size was set to six respondents. This exploratory sample size was '…studied in greater depth and more detail…' as Denscombe (Denscombe, 2010) suggested.

3.3.3 Piloting

The interview had to be clear, understandable and not suggestive or misleading (Saunders et al., 2016). This was achieved by piloting the questions as suggested by Adams et al. (2014)

and Saunders et al. (2016) with one of my former fellow students, a native English speaker. The piloting also gave insights into the broad wording, the order of questions and the time the interviews would take. Final questions and their rationale go in Appendix I

3.3.4 Conducting the Interviews

The semi-structured interviews with the respondents took place between 2 April 2021 and 6 April 2021. Given the COVID-19 epidemiological situation and the fact that the respondents are based worldwide, the interviews were conducted via the internet with the use of MS Teams. All the interviews were recorded with the built-in recording tool of MS Teams. The video files are automatically securely stored on the researchers Sharepoint (*Microsoft Teams | Group Chat, Team Chat & Collaboration*, 2021). This except for Interview 4, here Zoom (Zoom Video Communications Inc, 2021) and its embedded recording feature were used.

3.4 Analyzing primary data

The researcher manually transcribed all the interview audio files. The transcripts were manually analysed. The analysis was based on the findings of the literature review and key words in the transcripts. For this purpose and ease of reading, oral errors were corrected in the transcripts (Azevedo et al., 2017).

3.5 Bias

The researcher was aware of the possibility of both researcher and respondent bias (Adams et al., 2014; Gray, 2018; Saunders et al., 2019). Respondents can, for example, result in (1) answers to please the researcher (Adams et al., 2014; Gray, 2018), (2) holding back information because of confidentiality (Saunders et al., 2019), (3) giving faulty information (Adams et al., 2014). The assurance of anonymity and confidentiality can decrease respondent bias (Saunders et al., 2019). Furthermore, Saldaña (2013) stresses that any researcher should be extremely ethical with respondents, data and data analysis throughout the research project.

3.6 Ethical Considerations

This research has been conducted ethically under the University's Ethical Framework. Throughout the research, the researcher (1) followed the outlined research methodology, (2) minimized researcher bias in any way and (3) analyzed data in the most objective possible way. Qualitative research, however, cannot be verified in the same way as quantitative research (Denscombe, 2014).

3.7 Summary

This research was conducted within an Interpretist and Pragmatist Philosophy and an Inductive way of theory development using narrative inquiries in a Mono-method qualitative methodology on a cross-sectional Time Horizon. Figure 18 shows the methodology on Saunders' Research Onion.

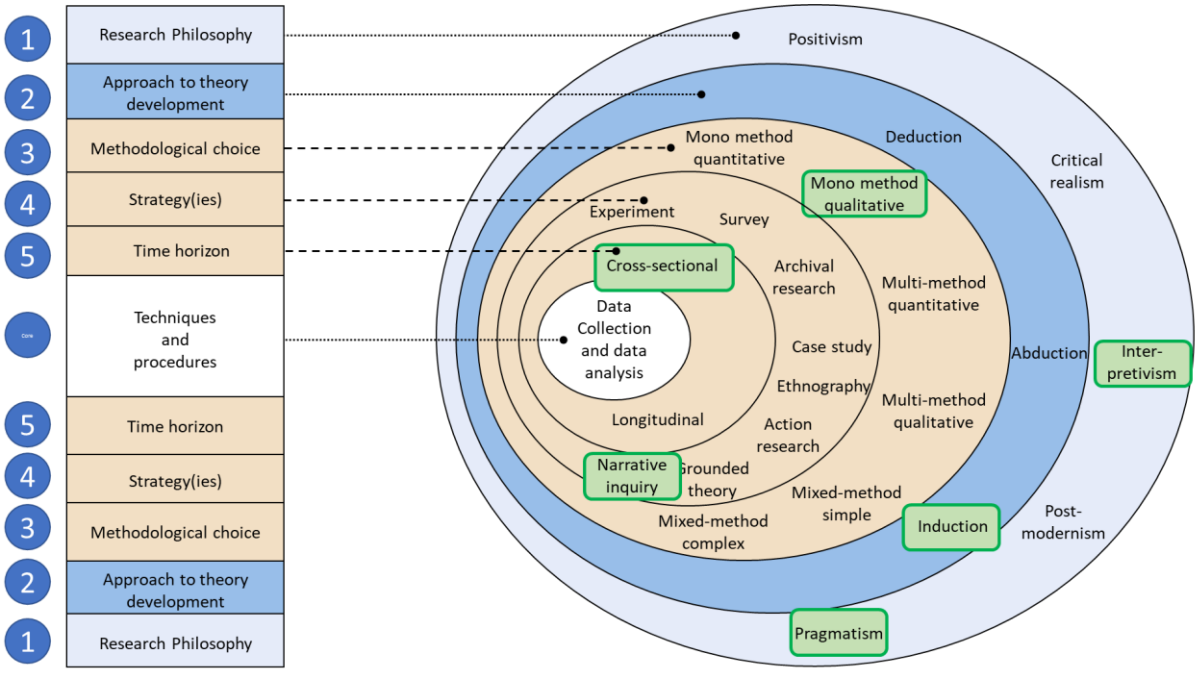


Figure 18: The used methodology projected on Saunders' Research Onion.

4 Results

4.1 Introduction

This study aims to research if the conventional elements of crowd safety and the tools to manage crowds are useful in coping with the possible transfer of respiratory viruses, such as COVID-19, on events, mass gatherings, and places of public assembly. In accordance with objective 3 and 4, as outlined in chapter 1.2, this chapter discusses and analyses the expert practitioners' views and experiences on how to embed the traditional views and methodology on crowd safety and crowd management to implement physical distancing to prevent the transfer of respiratory viruses.

4.2 Respondent profile and Interview Duration

The research consists of six one-on-one in-depth interviews. All respondents met both sample selection criteria as described earlier. Table 14 shows an overview of the respondents' profile; Table 13 shows interview duration. The transcription of the interview with Respondent 6 (R6) goes in Appendix L as an example.

Code	Job title	Criteria 1	Criteria 2
R1	Managing Partner	30 years of experience – Event security and crowd safety	Writes preventive concepts for events up to soccer stadiums.
R2	Event specialist at [redacted] National Police	6 years of experience – Assessment of safety and security plans for risk and high-risk events	Assessment of safety and security plans in the COVID-19 period
R3	Consultant	20 years of experience – Disaster management and registered nurse 20 years of experience – Production, and Safety and security in events	TV productions with audience, public flow management for a city
R4	Crowd Safety Manager Crowd Controller	40 years of experience – Crowd safety management and lecturer	Events during the pandemic in [redacted]
R5	Head of Security, Health and Safety [redacted] festival	20 years of experience – security and safety management in Live industry	Public flow management for a city, international work groups

Code	Job title	Criteria 1	Criteria 2
R6	Senior Consultant Crowd Safety Management	35 years of experience - production and safety management	Writes hygiene and infection protection concepts. Develops and teaches hygiene and infection protection courses.

Table 14: Respondent profile

#	Interview duration
1	00:41:28
2	00:55:18
3	01:21:19
4	02:10:10
5	00:52:10
6	01:29:05

Table 15: Interview duration

4.3 Crowd management

As crowd management lies at the core of this research, the respondents were asked what crowd management means to them, what definition of crowd management they uphold. Two of the respondents state that they abide by Fruin's definition. The majority of the experts (n=5) referred direct (D) or indirect (I) to the definition elements as suggested by Fruin (1993) (1) the element of preparation or planning, (2) the element of supervision or management, (3) the distinction between movement and assembly, (4) a link with design or context, (5) the importance of human behaviour and psychology, and (6) the intention of managing risk, as shown in Table 16.

Element of the definition of Crowd Management	1		2		3		4	5	6
	Planning	Risk Assessment	Operations	Management	Density	Movement	Design	Behaviour Psychology	Managing Risk Safety
R1	D	I	D	D	I	I	D	I	D
R2	D	I		I	D	D	I		D
R3	D	D	I	D	D	D	I	D	D
R4	D	I	D	D	I	I	D	I	I
R5	D	D	D	D	D	D	D	D	D
R6	D	D	D	D	D	D	D	D	D

D = direct reference / I = indirect reference

Table 16: Respondent Crowd Management Definition

Although crowd management and crowd control can merge (R3), the respondents (n=6) agree with the differentiation between the concepts of crowd management and crowd control as suggested by Fruin (1993) and place Crowd Management on the pro-active and planning side of events. Crowd Control is described as a curative tool to respond to emerging crowd issues, if necessary, with force. Almost 30 years after Fruin (1993) noted that the two concepts are wrongly used interchangeably, Respondent 5 makes the critical remark that:

> '…a lot of people think crowd control. Very few think crowd management.' (R5)

Furthermore, all respondents add an element of customer service as Berlonghi (1995), and Van de Sande (2013) did. Respondent 4 stated:

> 'If you can anticipate what the customer wants or needs before they need it, it's good customer service. And the same with crowd management, if you can plan it and think it through to the n^{th} degree...'. (R4)

Respondent 6 agrees and argues:

> '…It's one of the most important things of crowd management to understand the differences in space that we use and to find the right, the right figures and the right levels of quality to make sure that people have a good experience in any single area that they use.' (R6)

4.4 Crowd safety

On the matter of crowd safety, the respondents capture the root causality of 'traditional' crowd incidents and mention the characteristics, as proposed by Fruin (1971, 1984, 1993), Pauls (1984), Berlonghi (1993), Sime (1995), Still (2009, 2014a), the primary authors from the literature review on crowd safety. Table 17 summarises the analysis.

All Respondents mention design; more specific the use of the design and space is mentioned in detail. Respondent 3 poses the question and shows the need to link design and human behaviour, as Sime (1985) already mentioned.

> ‘How does your design work or how does your people will interact with your design of your venue?’ (R3)

Information, both within an organisation and with the crowd, referred to as ‘working with the audience’ (R5), is a factor for all the Respondents (n=6). Both Respondents 4 and 6 also link ‘Information’, the use of space, and the psychological aspects of the crowd as Pauls (1984), Sime (1985, 1995), Berlonghi (1995), Fruin (1993) and Still (2000, 2014a) suggested.

> ‘It's a permanent process in information directing, empowering people to do it right. […]…people are more or less self-competent. But we have to, we have to provide an environment where they can, where they can work, that they can understand. And we have to understand. We have to understand and with situations and in which what our environment is not self-explaining.’ (R6)

The management part is referred to as both managing risks as managing the crowd. Half of the respondents (n=3) mentioned crowd control measures as part of crowd safety. Respondent 1 argues:

> ‘…the main characteristics in crowd safety is to keep things flowing, to inform the people and to manage that the density is not, doesn't get too high, and the flow keeps people, keeps flowing where it's necessary. And to… if it gets too high, density or flow is interrupted or breaking down, then intervene with crowd control measures.’ (R1)

Respondent 4 takes it the other way around and argues that when talking crowd safety in opposition to crowd management:

> ‘…the word safety is in there now as opposed to management, so crowd safety becomes under crowd control. And if you can see something about having someone can get hurt, you've got to be able to step in.’ (R4)

Psychology and human behaviour are mentioned as factors by all Respondents, and all Respondents (n=6) break with the LeBonian tradition. Both Respondents 5 and 6 emphasize the knowledge, use and cultivation of the Theory on Shared Social Identity as proposed by literature (Drury and Reicher, 1999; Reicher, 2011; von Sivers et al., 2014; Templeton et al.,

2015, 2018). For the current covid-19 situation, Respondent 3 argues that, at least in his country, the use of the shared social identity, induced by the common faith of the pandemic (Drury, 2020), was minimal and that over time compliance with covid regulation decreased:

> ‘In my honest opinion. You know Bert, I see it from, from two sides. Not only from my experience in event safety but also as a health worker. Well, it's the problems… I see with our... in [redacted] and I see are that there is a low compliance in certain populations certain segments of our population who do really not comply with the, you know, the measures we are trying to take to counter or to combat covid-19. The shared identity we had in the beginning of the covid-19 pandemic; we saw among the people... it's actually gone. It's. We see it in the hospital all day, we have people who come to visit their next of kin and. Sometimes they flatly refused to take the necessary precautions. OK, so I don't think... I think the time of, of that shared social identity concerning covid-19 is gone in [redacted]. In [redacted], I cannot speak of any other situation.’ (R3)

Next to this, the proximate causes of death and serious injury, crowd density (force) and crowd flow are mentioned by all respondents (n=6). High crowd densities or staggering flow in bottlenecks and queues are recognised as dangerous to the level that predicting critical crowd densities becomes a goal in itself.

> ‘Well, I try to predict critical crowd densities. This is what I want to analyse if there is a situation that these densities can occur. At certain points, at certain times, certain locations.’ (R2)

	DESIGN			INFORMATION			MANAGEMENT			PSYCHOLOGY		FLOW			DENSITY FORCE	
	Design	Spatial Analysis	Routes (ICE)	Information	Work with crowd	Team communication	Risk Analysis	Management	Intervene with crowd control	Crowd/Human behaviour	Psychology	Crowd flow	Bottlenecks queues	ICE	Crowd Density	Manage Density
R1	✓			✓					✓		✓	✓	✓		✓	✓
R2	✓		✓	✓				✓			✓			✓		
R3	✓			✓			✓	✓	✓	✓	✓	✓		✓	✓	
R4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
R5	✓	✓	✓		✓			✓		✓	✓	✓	✓	✓	✓	✓
R6	✓	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓

Related to the: Root Causality of crowd incidents Proximate causality

Table 17: Crowd Safety Characteristics

4.5 Risk Analysis and Risk Analysis Tools

4.5.1 Pre-covid

Despite the fact that risk analysis is the foundation of professional safety and security plan for an event (van Duykeren, 2012), one Respondent (R4) argues that clients do not want to pay for an event risk analysis and do them themselves; unfortunately, those documents are most of the time out of date and copied from other events at the same venue.

When it comes to 'traditional' risk analysis methods, half of the Respondents (n=3) indicate that they have used a standardised risk management approach (ISO/ONR) pre-covid; Table 18 shows the details. Respondent 4 adds that the use of these systems depends on the client and size of the event. Most of the respondents (n=5) use the risk matrix approach based on likelihood and consequence.

	R1	R2	R3	R4	R5	R6
ISO 9000	✓					
ISO 31000				✓	✓	
ONR 49000	✓					
Risk Matrix	✓	✓	✓	✓	✓	

Table 18: Regular Risk Management Tools – used pre-covid.

When focusing on event- and crowd-oriented methods of risk analysis, see Table 19 for an overview, all Respondents (n=6) refer to the DIM-ICE Model as proposed by Still (2009, 2014a) and five Respondents couple this directly to RAMP Analysis, also developed by Still (2014a, 2014b). This method is in line with the Respondent vision on crowd safety and tackles both root and proximate causality of crowd incidents.

The RAMP analysis provides details to identify the possibility of factors contributing to high crowd density and flow, the main proximate contributors to injury and fatality. Respondent 1 formulates this as:

> '…mainly I use it [RAMP Analysis] as a theoretic framework, and I also use it as a method of doing things, getting in, analysing… getting seeing the problems, seeing how, how big is the problem. And then. Producing solutions on the field of design information management. … So, the main, main thing to analyse the crowd at my events is I used the RAMP analysis, which gave me a deeper insight... how the crowd will come to my place, moved to a place, and also behave on my place [venue].' (R1)

The details from the RAMP Analysis are linked to the manageable root causational factors of Design, Information and Management in the DIM-ICE Model.

In line with RAMP Analysis and the ICE component of the DIM-ICE Model, three Respondents document the customer journey and assess every service process on the possibility of queueing.

> '…my first model is that customers journey model. So, I follow, I follow my customer through… Well, at least at least the operate, operate, operations areas…' (R6)

All Respondents (n=6) use Queuing Theory to calculate the performance of service points. Two Respondents mention the use of Risk Mapping to document the findings of those calculations. Two Respondents use crowd simulation to assess manual queue calculations or when the situation is too complex to assess manually.

Tools (pre-covid)	R1	R2	R3	R4	R5	R6
DIM-ICE Model	✓	✓	✓	✓	✓	✓
RAMP Analysis	✓	✓	✓	✓	✓	✓
Customer Journey Model	✓	✓				✓
Queuing Theory (spreadsheet)	✓	✓	✓	✓	✓	✓
Risk Mapping	✓	✓				
Simulation		✓	✓			

Table 19: Event- and crowd-oriented Risk Management Tools – used pre-covid.

4.5.2 During covid

When discussing risk analysis in covid times, Respondent 6 argues that the government has already done the covid-19 risk assessment; the protection goals are already defined, in accordance with the literature review, the effective reproduction rate (R_e) of the virus has to drop.

> '…we have to look at our health system, our health system has not to break down. So, the analysis says if people meet and if the infection rate is high, our system will break down." (R6)

With the protection goals, government also provided generic non-pharmaceutical interventions (1) distancing, (2) face coverings, and (3) hygiene (R6), in line with the findings of the literature review.

> 'And they also offered us all the measures [tools]. They said, all right, here we go. You have to keep distance. You have to wear a mask. You have to clean up or disinfect areas. You have not to meet up with people.' (R6)

The only thing that needs to be done is implementing these measures in the event design and operation (R6). Alternatively, as Respondent 1 puts it:

> **'…** we look at air quality in locations. We look at sanitation where we have to clean areas which are more used places, so we will look at the transmission base of the covid-19 and then we alter the measures that we prevent the transmission via air, via droplets, via fomites and trying to analyse how high the risk is, or at least see why we have problems and improve the necessary measures.' (R1)

All Respondents (n=6) mention that, on the level of crowd management, in fact few things have changed; but ‘it’s just getting more and more deeper now’ (R1). The respondents that did not refer to the customer journey in the pre-covid context all do so in the covid context, direct or indirect. Emphasizing Respondent 1’s vision to look more detailed to all processes.

> ‘Before [covid], you would not have looked at the merchandise; how many people had the merchandise? You might have looked at the food and beverage to get more throughput, but nowadays you have to look how to put queues and something like that for these places you haven't done before.’ (R1)

When it comes to the tools, all Respondents (n=6) agree that the same tools are used (see Table 20). What changed is the density variable in the flow or queueing equation to facilitate physical distancing. This change brings the design factor, the available space, to the foreground when assessing queues under physical distancing.

> ‘Exactly the same tools. Because everything stayed the same. Only the parameters changed. […] So, the tools stayed exactly the same. Only the parameters that we put in the equation, they changed.’ (R2)

> ‘…the only thing we change is the way we look at the risks associated with densities. So, uh. We calculated the densities that are as a minimum necessary for... for safeguarding the social distancing. And for us was that zone was then instead of where we go, was that the red zone where you can't cross as a density. So, it's... just ... for me for the tools I use, It was just the shift of, of numbers, actually. (R3)

Tools (with covid)	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
DIM-ICE Model	✓	✓	✓	✓	✓	✓
RAMP Analysis	✓	✓	✓	✓	✓	✓
Customer Journey Model	✓	✓	✓	✓	✓	✓
Queuing Theory (spreadsheet)	✓	✓	✓	✓	✓	✓
Risk Mapping	✓	✓				
Simulation		✓	✓			
key	✓	= identical to pre-covid				
	✓	= added with covid				

Table 20: Event- and crowd-oriented Risk Management Tools – used with covid.

4.6 Density and Distancing

4.6.1 Density and Distancing

Density is recognised (n=6) as an important characteristic of crowd safety in general. Two respondents (R5, R6) directly referred to the Levels of Service as defined by Fruin (1971, 1987) for safety, comfort and facility. Respondent 5 created comparative drawings to assess areas, respondent 6 applies the scale and argues that:

> ‘We have to define the function [of an area] and make sure that we, that we find a kind of level of service, a level of quality, maybe more, to make sure this is the level of quality for that certain function.’ (R6)

The nature of the concept of distancing influences the variables in the core equations embedded in the tools for covid crowd risk analysis and crowd management. The need to keep a certain distance between entities translates into the area allocated per entity. The literature review showed that the way this area, or Personal Area Module, is measured is a point of discussion.

4.6.2 Technicalities of Distancing

Approach

The majority of Respondents (n=5) endorse the nose to nose method as used by Mumford et al. (2020) and documented by the SGSA (2020). On the one hand, the rationale behind this choice is found in the fact that for virus transmission, particles secreted through the nose or mouth need to be transferred to the mucous membranes of the nose, mouth, or eyes of a susceptible person. On the other hand, is this method more economical than the No-Touch method when it comes to capacity calculations.

On the matter of capacity, Respondent 3 notes that the total number of people who gather, with respect to distancing, does not matter unless the system fails.

> ‘…the [total] number of people [that gather] becomes important when you have a hiccup in your system. Then you have, you have, you know; you have more problems

> epidemiologically seen. Then, you have more, and risk of, of a broader transmission chain into your global population.' (R3)

Personal Area Module

When it comes to the definition of the Personal Area Module (PAM), Respondent 1 is undecided between the circle (C) and square (S) representation. Two additional Respondents (R3, R6) work with the square representation. A different (D) shape and system to maximise capacity for queues and static areas is developed by Respondent 4. Respondent 2 starts with the circle representation but switches to the square PAM as a safety margin.

> 'I start with the circle around this person, and of and of course, the hexagon is more effective, more efficient. But I'm not looking for efficiency. I'm looking for safety. So, I do it in a circle to see what is that square metres of this, what is the area of this circle. And then my safety margin, it is the square around the circle.' (R2)

As a result, most of the Respondents that spoke out on this subject (n=4 out of 5) align with Mumford et al. (2020) and SGSA (2020) and suggest the use of a square PAM, although the triangle tessellation with the hexagon PAM is more efficient (Steinhaus, 1983; Hales, 2000; Mumford et al., 2020), see Table 19 for details.

Static or Dynamic

Density thresholds under non-covid circumstances differ between static and more dynamic areas (Fruin, 1987; Still, 2014a). All Respondents (n=6) agree on this principle with distancing under covid. However, Respondent 4 makes the reservation that this difference is purely theoretical.

> '… you and I will walk [naturally] roughly one and a half meters away from each other. We might walk one meter, but if we are facing forwards. We're going to aspirate in front. So, I can see that people want to make a differentiation and want to spend hours about, you know, theoretical about how fast people are moving and everything else.' (R4)

For dynamic areas, Respondent 5 identifies not only the physical movement as a reason to assign more space to the PAM. Moving around the site increases the chance of interaction

with other people. Depending on the situation, the surrounding people might not all be in-group, resulting in more interpersonal distance. Respondent 1 recognises that extra space is not always at hand; therefore, other measures such as FFP2 masks need to be brought in and that the time when the safe distance is not respected is kept short.

4.6.3 Expressing the relation # people and area

Distancing has influenced the way of expressing the relation between the number of people and the available space for most Respondents (n=5). The expression of area per person aligns more with the visual image of keeping distance and is primarily used in communications. However, in the end, it comes back to people per square meter as it has always been.

4.7 Crowd Management Tools

The Respondents all (n=6) make a distinction between, on the one hand, crowd management tools for preparation, managing risk and development of measures, and on the other hand managing or controlling the crowd on site.

4.7.1 Preparation

When focusing on preparation-oriented tools and methods, all Respondents (n=6) state that the tools have not changed because of covid.

> '…it's the same tools. It's the same system. It's the same problems.' (R5)

As with the risk analysis, for all Respondents (n=6), covid brought more attention to the otherwise trivial processes and facilities within the customer journey.

> '…it's a much more intense relation [with the visitor] and, and communication level.' (R6)

All the Respondents (n=6) apply both the RAMP Analysis Model and DIM-ICE Model to study the situation with attention to the characteristics of crowd safety. Respondent 5 and 6 referred directly to Fruin's (1993) FIST. This way, both root and proximate causes of crowd incidents are covered. The tools mentioned by the Respondents are listed in Table 21.

> ‘…we use like, customers journey, DIM ICE, RAMP, while Fruin's FIST is always in the back.’ (R6)

With covid-19, both the Basic Flow Equation and Queueing Theory are applied throughout the whole customer journey by all Respondents (n=6); before covid, the same tools were used, but in-detail analysis was limited to the main services and facilities. Now, it becomes a search for the slowest server, as this defines the flow of the whole of a system (R6). These actual calculations are done with a spreadsheet (n=4) or by hand (n=2).

> ‘…for capacity is not just the question on physical distance and density in that I mean, in the event area, but I think that more or less like the number of toilets, number of bars and stuff available will have, still, already have a much higher influence on the calculation, on capacity…’ (R6)

Two Respondents have used Crowd Flow Simulations themselves. Simulation during covid is limited mainly because of the lack of opportunity to use the tool (R2, R3) and the cost (R1, R3, R4, R6). Next to this, there is a general reservation to the use of Crowd Flow Simulation:

> ‘…it's not better than the people who are actually putting in the input or reading the input.’ (R5)

Respondent 6 words it like this:

> ‘… so many companies offering simulations which are computer experts and simulation experts but have no clue on crowd management at all. […] you need experts to understand the whole process. The question beforehand, you need experts on the, on the simulation side so they understand crowd management and crowd behaviour. And you only have to have people to ask the right questions to understand the results and then find the right solutions with the results. […] If you have that. I'm fine with simulations. (R6)

The tools are used for analysis and development of measures and as a means of communications. All Respondents (n=6) mention tools used for visual communication.

Respondent 4 emphasises strongly on the use of visual communication and planning tools as a replacement for long text documents.

> ‘I think in pictures and I plan in pictures, then when I'm out there, I don't have to pull out a 50-page document…’ (R4)

All respondents have knowledge of crowd psychology and see this as a tool to manage crowds. Concepts as ‘mass panic’ and ‘stampedes’ are critically approached, and the crowd is seen as an ally.

> ‘…the problem is in the physics and not in the psychology. OK. We all make mistakes in management, design and information and not people get panicked and then they die.’ (R1)

Respondents 4 and 6 refer to the incident at the Love Parade in Duisburg in 2010:

> ‘…people were going at embankments and light towers on that sea container... like the toilet, the sea container up and people were pulling them over and they were doing that, even as far back as Hillsborough... people trying to get out. They're not panicking. Here mate grab my hand... Let's pull you up...’ (R4)

The concept of a shared social identity, as illustrated in Duisburg and Hillsborough (R4, R6), is carried out by all Respondents (n=6), mostly in the communications strategy.

> ‘I implement it, and I most… the main place where I keep it. This identity theory in mind, it is with my communication strategy. So how to communicate to the people to create and to increase this feeling of shared social identity …’ (R1)

Respondent 5 goes the extra mile and takes the concept to colour the uniform of the crew on the ground.

> ‘…our uniform in our company […] is a light blue uniform. It's light blue because it is friendly. It is inviting people to come and talk to us…’ (R5)

Preparation Tools (with covid)	R1	R2	R3	R4	R5	R6
DIM-ICE Model	✓	✓	✓	✓	✓	✓
RAMP Analysis	✓	✓	✓	✓	✓	✓
Customer Journey Model	✓	✓	✓	✓	✓	✓
Queuing Theory	✓	✓	✓	✓	✓	✓
Flow equation	✓	✓	✓	✓	✓	✓
Hand calculation/calculator	✓	✓				
Spreadsheet	✓	✓	✓		✓	
Simulation		✓	✓			
Visual Communication & Planning (Risk Mapping, 3D RTDS, Google Earth Pro, Google Earth Studio, Autocad, Iventis, One Plan, We Track, Halo, Crowd View)	✓	✓	✓	✓	✓	✓
Crowd Psychology	✓	✓	✓	✓	✓	✓
key	✓	= identical to pre-covid				
	✓	= added with covid				

Table 21: Event- and crowd-oriented Preparation Tools.

4.7.2 Operation

The Respondents agree with Fruin (1993) on the fact that crowd management contains an operational factor. For this, all the respondents (n=6) value supervision and management by staff the most.

> ‘You can't only just write and concept, but not be on-site to look whether the concept works or not and what shall work is that we, that we have and that we have an eye on the crowd…’ (R6)

Two Respondents (R2, R5) mentioned big data, mobile phone operator data or Wi-Fi-based data but argued that these tools are not ready and too complicated.

> ‘they are not developed enough yet. I think I trust my eye the most.’ (R2)

In line with this, cameras are implemented as ‘just’ an extra pair of eyes. When it comes to capacity monitoring, all Respondents who mentioned a camera-based people counting system (n=3) argue that these systems are not ideal for temporary setups because of the time needed for calibration.

> ‘…but it [camera-based counting] showed that it didn't work because the calibration needs to be done before it actually works. And that means that they spent the first three

days and not being able to work and on the last day it worked, that doesn't work for a festival.' (R5)

Four Respondents referred to a manual people count as the most reliable and workable system; the numbers can be fed to a dashboard used by the control room.

During operation, communication, driven by the notion of a shared social identity' and efforts to become in-group, is mentioned throughout all interviews (n=6) and has shifted to a higher frequency (R6) during covid.

Operation Tools (with covid)	R1	R2	R3	R4	R5	R6
Communication with the crowd	✓	✓	✓	✓	✓	✓
Management by Staff	✓	✓	✓	✓	✓	✓
Camera-based Count		✓	✓		✓	
Manual Count		✓	✓	✓	✓	
WIFI or operator DATA	✓	✓	✓	✓	✓	✓
CCTV		✓	✓	✓	✓	✓
key ✓	= identical to pre-covid					
✓	= mentioned, but not ideal for temporary setups					

Table 22: Event- and crowd-oriented Operational Tools.

4.8 Summary

The tools to develop safety measures and the tools to analyse risk work with the same basic variables that define likelihood and impact and are often the same tool. In the risk analysis context, the as-is (or to be) situation is looked upon and evaluated. When developing safety measures, the variables are modified to lower likelihood and/or impact. In the context of crowd safety, Design, Information, Management and Behaviour are tweaked to influence density and flow, and as such, crowd safety, comfort, and satisfaction.

Covid-19 did not change the view on crowd management or the tools used for risk analysis, measure development or monitoring and managing during operation. It is only the values assigned to the defining variables that are adapted to the epidemiological situation and legislation. Table 23 shows the crowd management tools as mentioned by the Respondents, on a timeline from Risk Analysis and the development of measures during Preparation to monitoring and managing during operation.

Phase	Goal	Tool	R1	R2	R3	R4	R5	R6
Preparation	Risk Analysis (general)	ISO 9000	✓					
		ISO 31000				✓	✓	
		ONR 49000	✓					
		Risk Matrix	✓	✓	✓	✓	✓	
	Risk Analysis (event/crowd)	DIM-ICE Model	✓	✓	✓	✓	✓	✓
		RAMP Analysis	✓	✓	✓	✓	✓	✓
		Customer Journey Model	✓	✓	✓	✓	✓	✓
		Queuing Theory	✓	✓	✓	✓	✓	✓
		Risk Mapping	✓	✓				
		Simulation		✓	✓			
	Development of Measures	DIM-ICE Model	✓	✓	✓	✓	✓	✓
		RAMP Analysis	✓	✓	✓	✓	✓	✓
		Customer Journey Model	✓	✓	✓	✓	✓	✓
		Queuing Theory	✓	✓	✓	✓	✓	✓
		Flow equation	✓	✓	✓	✓	✓	✓
		Hand calculation/calculator	✓	✓				
		Spreadsheet	✓	✓	✓		✓	
		Simulation		✓	✓			
		Visual Communication & Planning tools*	✓	✓	✓	✓	✓	✓
		Crowd Psychology	✓	✓	✓	✓	✓	✓
Operation	Managing	Communication with crowd	✓	✓	✓	✓	✓	✓
		Psychology	✓	✓	✓	✓	✓	✓
		Management by Staff	✓	✓	✓	✓	✓	✓
	Monitoring	Management by Staff	✓	✓	✓	✓	✓	✓
		Camera-based Count		✓	✓		✓	
		Manual Count		✓	✓	✓	✓	
		WIFI or operator DATA	✓	✓	✓	✓	✓	✓
		CCTV		✓	✓	✓	✓	✓

Key		
	✓	= identical to pre-covid
		= added with covid
		= mentioned, but not ideal for temporary setups

* Risk Mapping, 3D RTDS, Google Earth Pro, Google Earth Studio, Autocad, Iventis, One Plan We Track, Halo, Crowd View

Table 23: Project Timeline with Crowd Management Tools

5 Discussion/Conclusions

5.1 Objective 1 – To critically review the academic literature regarding the transfer of respiratory viruses, such as COVID-19, and the non-pharmaceutical interventions to prevent transfer.

Literature showed the three ways of virus transmission for respiratory viruses such as SARS-CoV-2: (1) droplets, (2) aerosol, and (3) fomites. The literature proposes three primary non-pharmaceutical interventions: (1) distancing, (2) Personal Protection Equipment (PPE) such as face coverings, and (3) hygiene. These non-pharmaceutical interventions are highly behaviour orientated, and the shared social identity that potentially comes with a pandemic must be nurtured and can be used to increase situational awareness and compliance with the rules and measures linked to the interventions. Physical distancing, however, needs to be facilitated and is a crowd management issue touching Design, Density and Behaviour. Figure 19 connects the transfer modes of respiratory viruses with the primary non-pharmaceutical interventions.

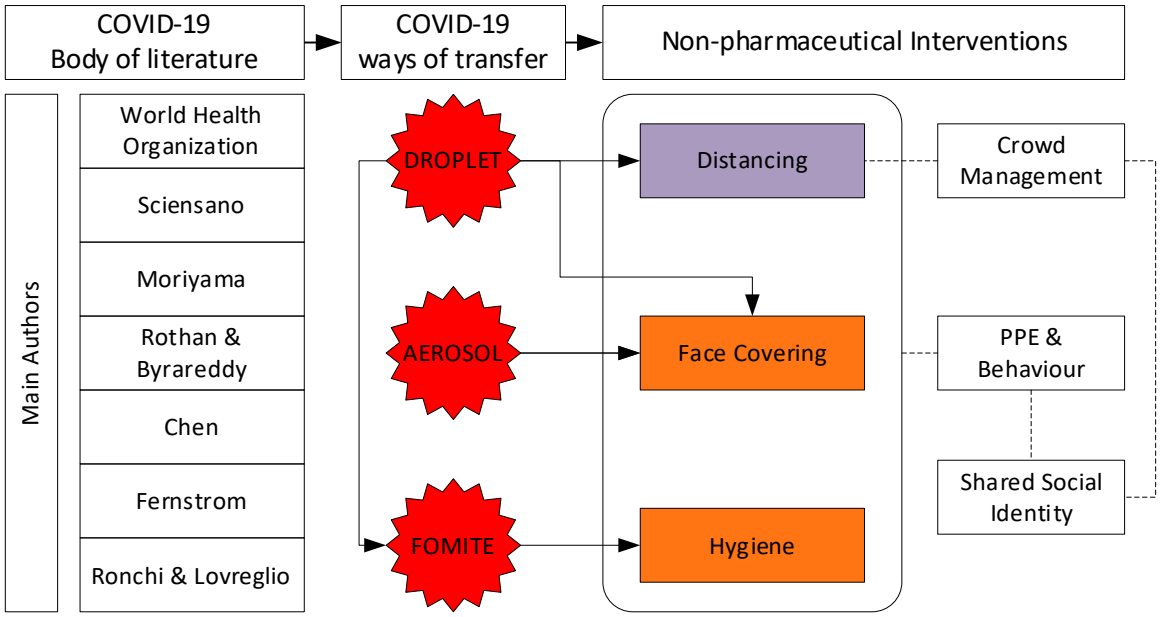


Figure 19: Respiratory Viruses - transmission and non-pharmaceutical interventions

5.2 Objective 2 – To critically review the academic literature regarding crowd safety and crowd management tools.

Literature provided definitions of crowd management all of which embed (1) the element of preparation, (2) the element of management, (3) the distinction between static and dynamic areas, (4) a link with design, (5) the importance of human behaviour and psychology, and (6) the intention of managing risk.

When it comes to crowd safety, six leading authors (Fruin, Pauls, Berlonghi, Sime, Still, and Drury) with backgrounds in both psychology and engineering agree on the main characteristics of crowd safety. The characteristics of (1) Design, (2) Information, (3) Management, and (4) Psychology (or behaviour) capture root causality of crowd related incidents. These are combined in the DIM-ICE Model (Figure 20) as developed by Still. Whilst (5) Density (Force), and (6) flow capture the main proximate contributors to injury and fatality in crowd related incidents.

		ICE 'Time'			
		INGRESS	**CIRCULATION**		**EGRESS**
DIM	**DESIGN**	BEHAVIOR PSYCHOLOGY	FORCE/MOVEMENT/ BEHAVIOUR	CROWD BEHAVIOUR MOVEMENT	ENERGY Out of Control
		SPACE Force	DESIGN	DESIGN & Engineering	PHYSICAL CONDITIONS Unsafe
	INFORMATION	INFORMATION	COMMUNICATIONS	COMMUNICATIONS Technology	COMMUNICATIONS Poor
	MANAGEMENT	CROWD MANAGEMENT	CROWD MANAGEMENT	CROWD MANAGEMENT	MANAGEMENT PLANNING inadequate
		Fruin	Pauls	Sime	Berlonghi

Figure 20: Crowd Safety Characteristics capturing Root Causality combined in the DIM-ICE Model

On the level of risk analysis, crowd safety is to be seen in the broader aspect of risk management. Standardised risk management processes such as ISO, or ISO-like, can be used in the context of mass gathering situations. When the Pedestrian Planning Process as defined by Fruin is placed in the context of crowd safety with the goal to mitigate or transfer risk, the same structured approach is followed as with the ISO standardised process, see Figure 21, (1) define context and goal, (2) study and (risk) analysis, and (3) develop measures to meet the defined goals.

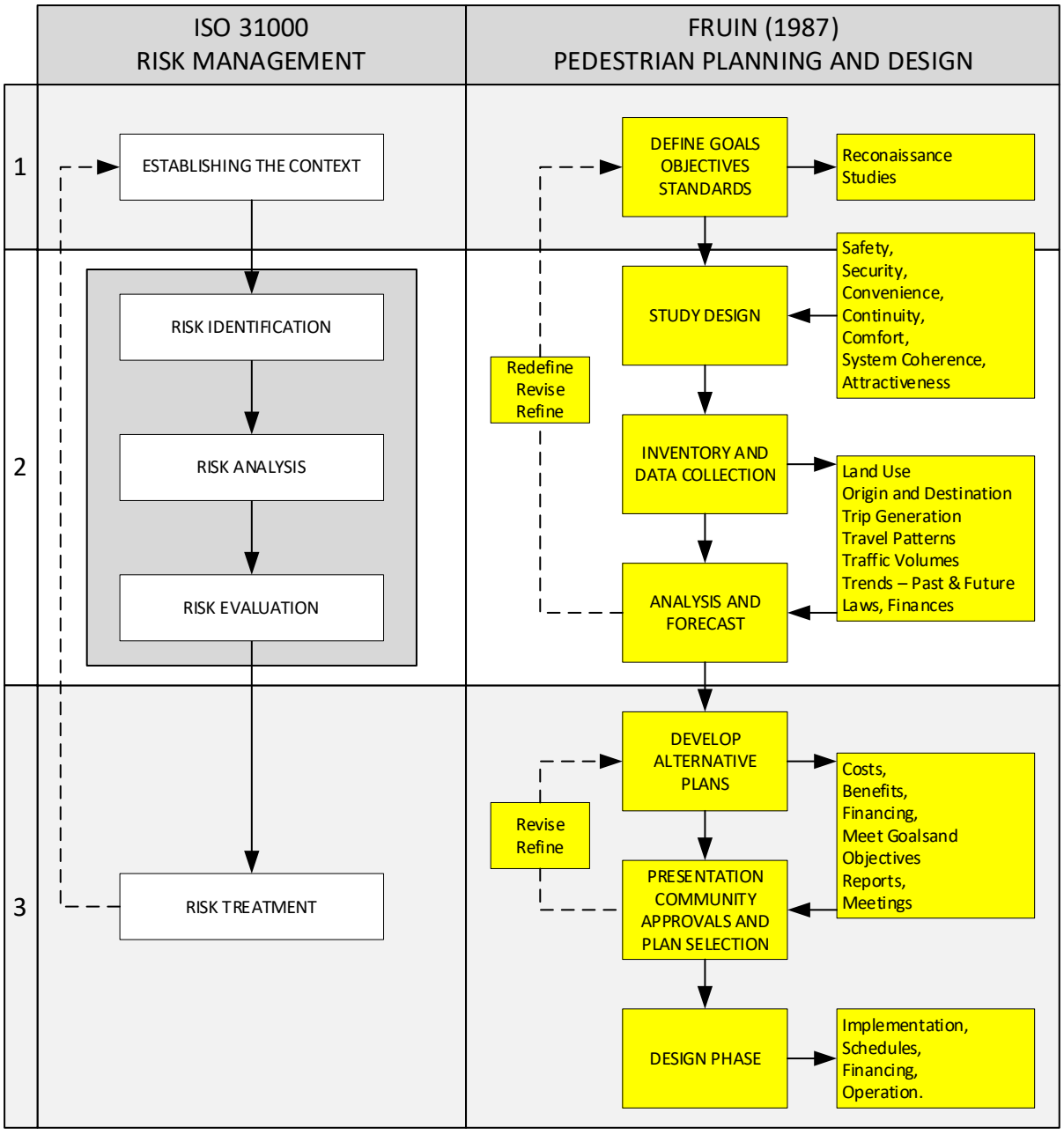


Figure 21: ISO 31000 Risk Management Process Overview vs Fruin (1987) Pedestrian Planning Process

Risk analysis should be the core of any safety and security plan and must embed the characteristics of crowd safety. If the situation requires, the risk of transferring respiratory viruses should be embedded in the risk management approach. It is, in times of pandemic, however, important not to neglect other risks such as terror or simple slips, trips and falls.

The non-pharmaceutical interventions for respiratory viruses, and crowd management and crowd safety are joined by the concept of physical distancing. The concept of physical distancing enforces itself on the area needed per person, the PAM. Whereas crowd management and crowd safety in the past focused on areas with densities above one person per square meter if we follow the Still definition, or areas from 3 people per square meter and up for static event areas, physical distancing changes these thresholds. Influenced by the Distancing Value (D), the Personal Area Module increases, and densities drop. Lower densities result in lower allowed capacities. This brings the technicalities of distancing and density to the foreground. Two ways of measuring distancing are proposed by literature (1) nose to nose, and (2) body to body or ‘no touch’; next to this, the area calculation of the PAM is discussed as well. The PAM can be represented as (1) a square, (2) a circle, or (3) the circumscribed hexagon of the circle. Both influencing the needed area per person, and thus PAM, Density, Capacity and eventually possible event revenue. Both literature and the Respondents tend to go for the nose-to-nose method with a square-shaped PAM, as was common before covid.

The elements of crowd safety are embedded in traditional crowd management tools as described by literature. The element of Density and those closely related to it, Design and Flow, are found in nearly all the traditional tools. This suggests that these tools can facilitate physical distancing as proposed by the body of literature on respiratory viruses; see Figure 22 for a summary. Literature and all the Respondents agree on the fact that knowledge of crowd behaviour and crowd psychology as a tool can assist in increased compliance with regulations.

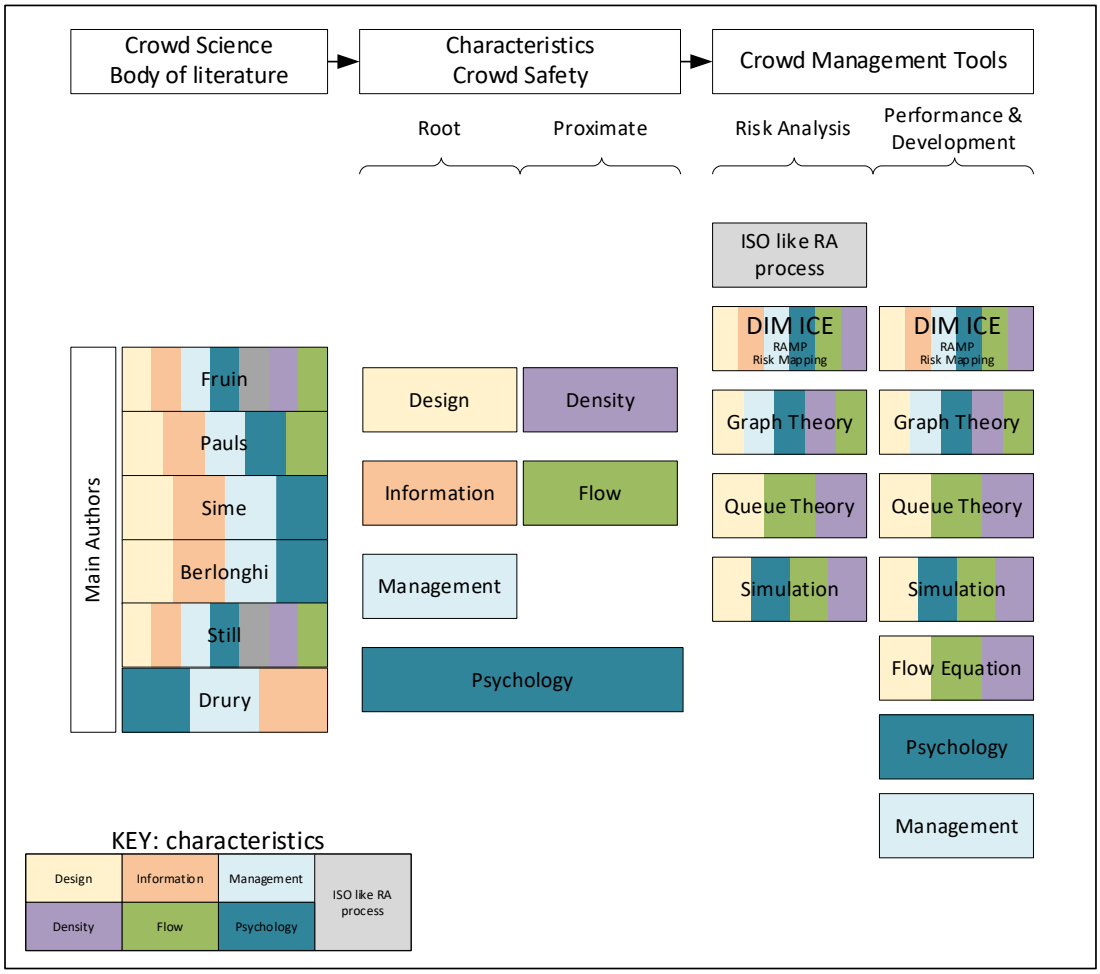


Figure 22: Characteristics of Crowd Safety – schematic

5.3 Objective 3 – To investigate practitioners' views and experiences (event managers, safety/security managers, licensers) when implementing crowd safety and crowd management tools.

The definition of crowd management as proposed by Fruin (1993 has proven to stand the test of time as the experts agree with Fruin and define two ‘phases’ in the crowd management process. First of all, there is a comprehensive preparation or planning phase where analysis of the ‘as is’ or proposed ‘to be’ situation is accompanied by a risk management process. Second, the experts define an operational phase where the crowd is monitored and managed. With human/crowd behaviour as a common thread through the whole process.

Notable is the fact that customer service is built in the definition of crowd management by all the experts. With this generally accepted view, crowd management on events, mass

gatherings and places of public assembly no longer restricts itself to safety but enters the world of facility where the whole customer journey becomes of interest.

Design, Information and Management, with a constant backcheck to psychology, are found in the vision on crowd safety of all the experts. Density and flow are defined as the main risks under non-covid situations, and the concept of level of service is carried out as a way of looking at density and flow. In doing so, both Root and Proximate Causality are dealt with in the risk management process.

Standardised risk management processes have not been adopted by all experts, although the classic questions of risk assessment are embedded in their approach. The use of a risk matrix embedding likelihood and consequence on a qualitative scale is a widespread technique. The DIM ICE Model, and the accompanying tools of RAMP Analysis and Risk Mapping, is by far the most widespread methodology for crowd risk analysis. For in detail study of flow, all experts use Queueing Theory or derived methods. Few experts use crowd flow simulations, mainly because of the costs involved and the need for both simulation and crowd management expertise when running simulations and assessing simulation results.

Other tools during preparation are elements of Graph Theory to analyse and document the customer journey in combination with the basic flow equation. Each expert has built their own (spreadsheet) system to manage these elements.

A common theme between experts is also the need for visualisation. Visualising risk or mitigating measures is deemed important for quick and easy communication as a picture speaks a thousand words. The standard crowd management tools, as mentioned, have a visual aspect, Table 24. The use of commercial Visual Communication & Planning tools, however, is not widespread. However, one expert goes great lengths to use these tools instead of creating bulky documents.

Tool	Visual Aspect
ISO type Risk Analysis	Not applicable
Risk Matrix	Standard format Colour coded qualitative scale
DIM-ICE Model	Standard format Colour coded qualitative scale
RAMP Analysis	Often worked out in drawings
Graph Theory (customer journey)	Standard format Models the site
Queuing Theory	Not applicable
Risk Mapping	Map-based Colour coded qualitative scale
Simulation	2D and 3D video output
Flow equation	Not applicable
Crowd Psychology	Not applicable

Table 24: Visual Aspects of the Crowd Management Tools

5.4 Objective 4 – To analyse if and how events, mass gatherings, and places of public assembly embed the traditional views and methodology on crowd safety and crowd management to implement non-pharmaceutical interventions to prevent the transfer of respiratory viruses such as COVID-19.

No changes in the overall approach and tools

The experts are unanimous on the fact that Covid-19 did not change the view on crowd management or the tools used for risk analysis, measure development or monitoring and managing during operation.

Within the covid-19 risk management process are the protection goals defined by academic literature embedded in government rules and laws. Transmission of the SARS-CoV-2 virus via droplets, aerosols and fomites must be prevented.

The traditional tools as used by the experts embed the elements of crowd safety, including Density, see Table 26. This is the main element involved in planning for Physical Distancing.

When it comes to separating flows or creating one-way routes, the element of flow comes into play.

Tool	Design	Information	Management	Psychology	Flow	Density
ISO type Risk Analysis						
Risk Matrix						
DIM-ICE Model						
RAMP Analysis						
Graph Theory (customer journey)						
Queuing Theory						
Risk Mapping						
Simulation						
Flow equation						
Crowd Psychology						

Table 25: Crowd Management Tools and the Crowd Safety Characteristics.

Adjusted Thresholds

What has changed under covid and the concept of physical distancing are the safe density thresholds. Planning for physical distancing results in significant lower densities and capacities. Despite the effect on density, capacity, and the economic viability of commercial events, the experts did not de facto opt for the most economical methods of measuring physical distance and representing the Personal Area Module, as shown in Table 26.

Item	R1	R2	R3	R4	R5	R6
How to measure?	N2N	N2N	N2N	N2N	N2N	NoTo
PAM shape?	S/C	S	S	D	No data	S
Differentiation static/dynamic?	Yes	Yes	Yes	Yes	Yes	Yes
Key	N2N = Nose to Nose / NoTo = No touch S = Square / C = Circle / D = Different					

Table 26: Interview results Density and distancing

Another consequence of the lowered density thresholds under covid is the fact that seemingly riskless or low-risk processes on the customer journey become of more interest. All experts have more attention to the whole customer journey under covid the analysis has become more

detailed and deeper. Every facility with a possible queue becomes a risk. By doing this, the other non-pharmaceutical interventions of (hand) hygiene enter the crowd safety plan. These hygiene facilities are prone to queues and congestion.

During operation, capacity monitoring has gained importance. Counting in and outgoing visitors has become standard operation. A manual count, possibly fed into a computer system, is preferred above camera-based systems, especially with temporary setups. This ‘boots on the ground’ approach is continued throughout the whole operational phase for monitoring, communication and management.

On the level of crowd psychology, the focus is on communication. The experts have abandoned the LeBonian tradition and focus on collective and individual resilience through a strong and nurtured shared social identity. Communication must be perceived as from ingroup and reliable.

Planning for covid-19

The way the experts embed the traditional views and methodology on crowd safety and crowd management can be summarised as shown in Figure 23. The methodology follows the main steps of the Pedestrian Planning Process as defined by Fruin.

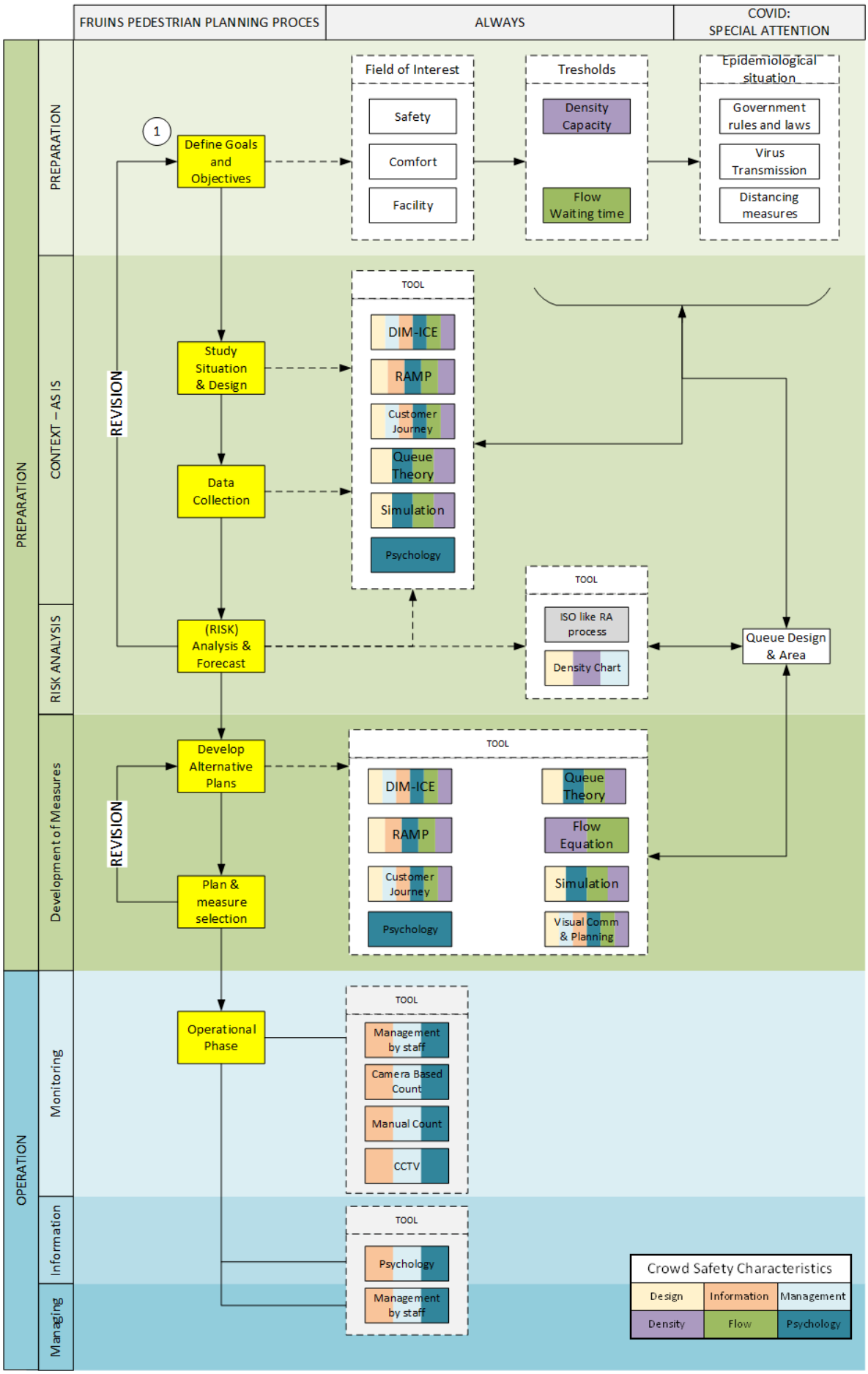


Figure 23 – Planning for covid-19

5.5 Objective 5 – To draw conclusions and make recommendations to event(safety) managers on the future strategy for coping with events and places of public assembly in the case of respiratory virus outbreak.

5.5.1 Conclusions

Conclusion 1

The traditional views and methodology on crowd safety and crowd management can be used to implement the non-pharmaceutical intervention of physical distancing and can help organise the implementation of hygiene measures on events, mass gatherings and places of public assembly.

Conclusion 2

The traditional crowd management and crowd safety tools can be used to implement the non-pharmaceutical intervention of physical distancing and can help organise the implementation of hygiene measures on events, mass gatherings and places of public assembly. See Figure 24 and Appendix H.

When it comes to facilitating or planning for physical distancing, the variables in the traditional tools must be adapted in line with the epidemiological situation and local regulation.

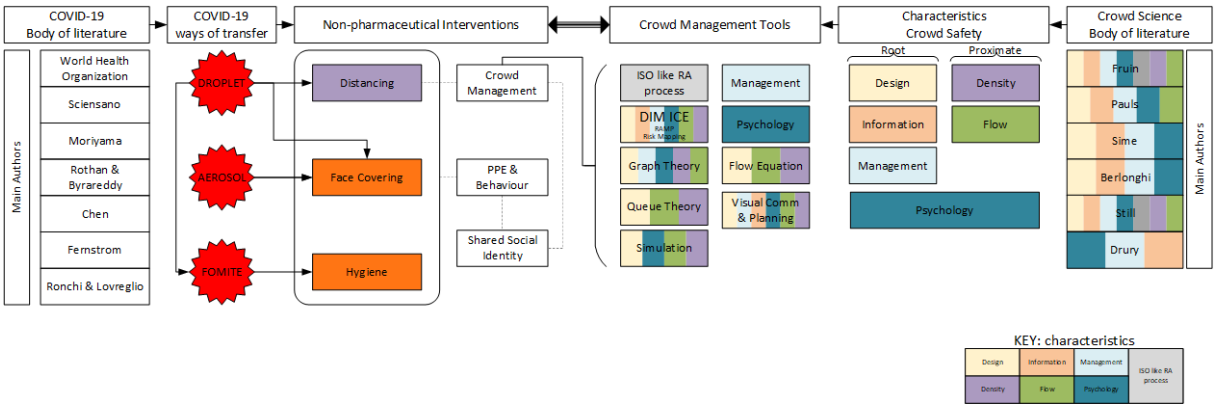


Figure 24: Crowd Management Tools vs Virus Transmission

5.5.2 Recommendations

Recommendation 1

It would be positive for the industry to agree on the technicalities of physical distancing. Broader research on this topic could lead to industry and global consensus on the technicalities of physical distancing. When the industry speaks as one, its voice carries further.

Recommendation 2

In times of outbreak of respiratory viruses, such as covid-19, the knowledge and expertise of crowd (safety) managers can be deployed to:

1. Cope with the virus, not only in an event context but in the context of mass gatherings and places of public assembly.
2. Plan for reopening of society after lockdown.

Recommendation 3

Use Visual Communication and Visual Planning Tools to (1) analyse context and design, (2) analyse and assess risk, and (3) implement and communicate on measures. It is to be noted, though, that Visual Tools must be grounded in theory.

Recommendation 4

Based on the literature review and the expert interviews, a Covid Concept Planning process is presented; see Figure 25 for an overview. The seven-step process aligns with Fruins pedestrian planning process, and the basic ISO structure on risk management embeds the crowd management tools and output documentation per step.

STEP 1 Define Goals and Objectives

For every project, the goals and objectives need to be defined. In the context of planning for covid, this comes down to defining density, capacity and waiting time thresholds in line with local regulation and the epidemiological situation.

Tools: Information on the epidemiological situation and applicable regulation and law

Output Thresholds for density, capacity and waiting time.

STEP 2 Project Analysis

The project is analysed along with the visitor profile and venue details.

Tools: DIM-ICE Model, RAMP Analysis, Graph Theory (customer journey)

Output Information and details on Design, Information and Management

Docs: RAMP Analysis, Customer journey model/network

STEP 3 Covid Risk Analysis & Forecast

The obtained project details are analysed as a function of the set goals and objectives from step 1. In the covid context, this comes down to the prevent virus transmission through non-pharmaceutical interventions.

Tools: ISO-like Risk Analysis process, DIM-ICE Model, RAMP Analysis, Risk Mapping, Graph Theory (customer journey), Queue Theory, Flow Equation, Simulation, (crowd) psychology

Output: Risk Details

Docs: DIM-ICE Model, ISO-like Risk Analysis, Capacity Analysis, Crowd Flow Analysis, Queue Analysis, Risk maps: High Touch charts & Density Charts

STEP 4 Develop Measures & Alternative Plans

Based on the insights of the project details and the (risk) analysis, measures can be developed to meet the project goals and objectives. The appropriate measures are selected, cost and available resources are taken into account. The selected measures are further developed to fit the project and the goals and objectives.

Tools: DIM-ICE Model, RAMP Analysis, Risk Mapping, Graph Theory (customer journey), Queue Theory, Flow Equation, Simulation, (crowd) psychology, Information, Visual Communication & Planning Tools, human resources, hardware & consumable resources.

Output: Covid Prevention Concept

Docs: Details of measures & Alternative plans, Staff plan, Security plan, Cost estimate for HR, Cost Estimate for hardware & Consumables

STEP 5 Check with stakeholders

The concept plan is checked with all stakeholders: local government, emergency services and inhouse departments (HR, facility, technical…)

Tools: Information and feedback from stakeholders

Output: Approved Covid Prevention Concept

STEP 6 Implement covid prevention concept

The approved Covid Prevention Concept is put into operation, all Design, Information and Management measures are implemented.

Tools: The approved Covid Prevention Plan, Visual Planning Tools, Psychology, Staff, Hardware and consumables, Monitoring system

Output Crowd Management Operation

Docs: To-be-built plans, Staff briefing, Organigram, Hardware and Consumables details, Info & Visuals Crowd

STEP 7 Coordinate and Evaluate

The crowd management operation is managed on-site, information is shared with the crowd, and emerging issues are dealt with.

Tools: Control room, communication with staff and visitors, psychology, HR, Hardware

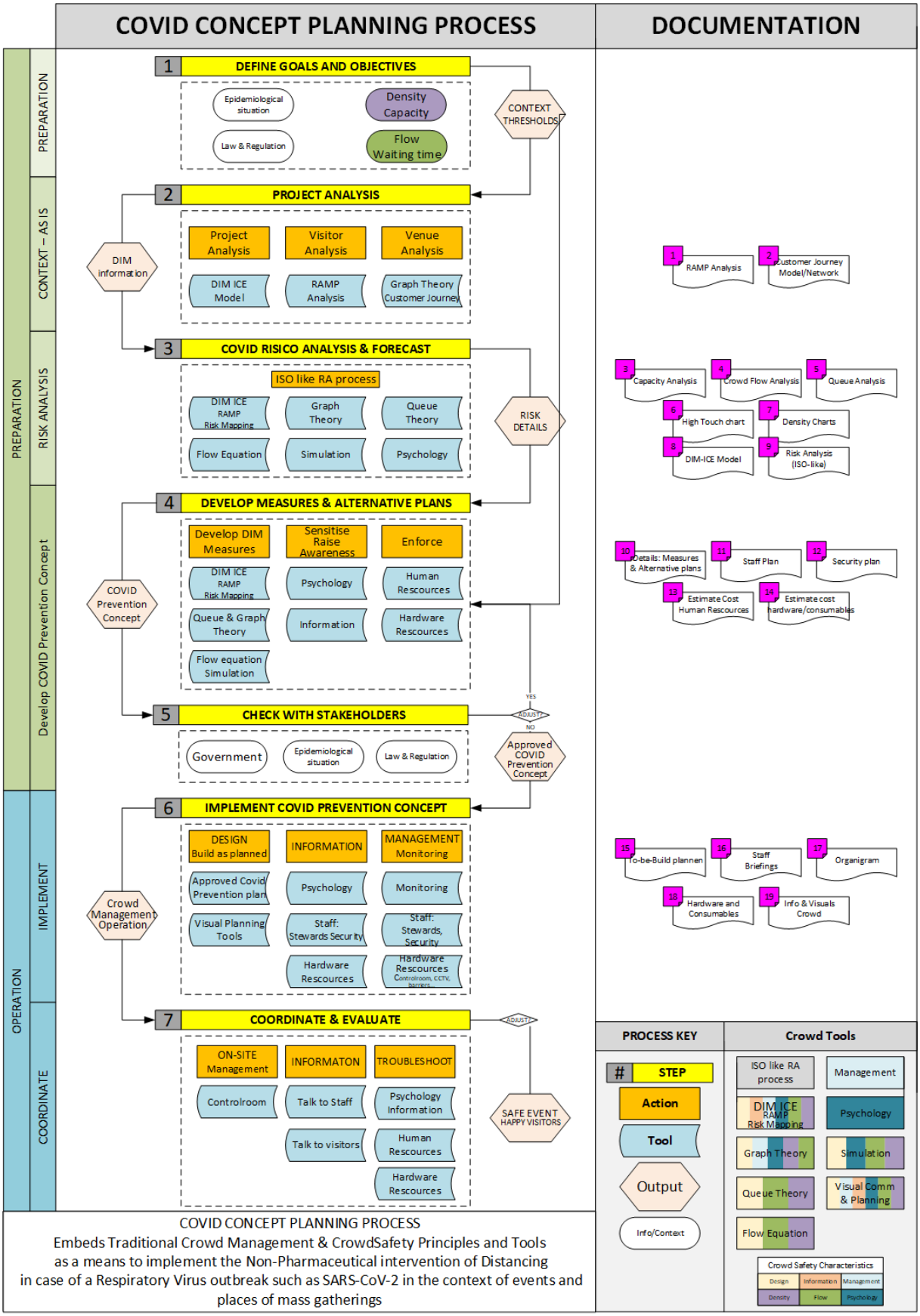


Figure 25: Recommendation 2 - Covid Concept Planning Process

6 References

About Hungary (2020) *About Hungary - Coronavirus Update: 4,448 confirmed COVID-19 cases in Hungary*. [Online] [Accessed on 27th July 2020] http://abouthungary.hu/news-in-brief/coronavirus-update-4448-confirmed-covid-19-cases-in-hungary/.

Ackx, R. and Duijndam, H. (2006) 'Syllabus DHM Security Management.' DHM Instituut.

Adams, J., Khan, H. T. A. and Raeside, R. (2014) *Research methods for business and social science students*. Second edition, Los Angeles: SAGE.

Agraa, O. M. and Whitehead, B. (1968) 'A study of movement in a school building.' *Building Science*, 2(4) pp. 279–289.

Ahmed, A. (2008) 'Ontological, Epistemological and Methodological Assumptions: Qualitative Versus Quantitative' p. 14.

Ahmed, Q. A. and Memish, Z. A. (2020) 'The cancellation of mass gatherings (MGs)? Decision making in the time of COVID-19.' *Travel Medicine and Infectious Disease*, March, p. 101631.

Al Jazeera (2020) *Dozens killed in stampede at Qassem Soleimani's funeral in Iran*. Al Jazeera. [Online] [Accessed on 23rd November 2020] https://www.aljazeera.com/news/2020/1/8/dozens-killed-in-stampede-at-qassem-soleimanis-funeral-in-iran.

Algemeen Pharmaceutische Bond (2020) *Coronavirus desinfectie handen oppervlakten 19/03/20*. https://www.apb.be. [Online] [Accessed on 4th June 2020] https://www.apb.be/APB%20Documents/NL/All%20partners/CORONAVIRUS_DESINFECTIE_HANDEN_OPPERVLAKTEN_19_03_20.pdf.

Alimohamadi, Y., Taghdir, M. and Sepandi, M. (2020) 'Estimate of the Basic Reproduction Number for COVID-19: A Systematic Review and Meta-analysis.' *Journal of Preventive Medicine and Public Health*, 53(3) pp. 151–157.

AllAssignmentHelpUK (2017) 'Research Onion - Made easy to understand and follow.' Best Articles. 14th July. [Online] [Accessed on 10th August 2020] https://www.allassignmenthelp.co.uk/blog/research-onion-made-easy-to-understand-and-follow/.

Almeida, J. E., Tavares, R. M., Araújo, S. B., Coelho, A. L. and Cordeiro, E. (2016) 'The use of Pathfinder as an evacuation planning tool, a case study in concert halls.'

Alvarez, P., Leeson, A. and Alonso, V. (2016) 'Modelling large scale evacuations to build safer cities.' *Transportation Professional*.

Anderson, R. M. and May, R. M. (2010) *Infectious diseases of humans: dynamics and control*. Reprinted, Oxford: Oxford Univ. Press.

Arksey, H. and Knight, P. (1999) *Interviewing for Social Scientists*. 1 Oliver's Yard, 55 City Road, London England EC1Y 1SP United Kingdom: SAGE Publications, Ltd.

Asadi, S., Bouvier, N., Wexler, A. S. and Ristenpart, W. D. (2020) 'The coronavirus pandemic and aerosols: Does COVID-19 transmit via expiratory particles?' *Aerosol Science and Technology*. Taylor & Francis, 54(6) pp. 635–638.

Atwood, L. E. and Major, A. M. (2000) ‘Optimism, pessimism, and communication behavior in response to an earthquake prediction.’ *Public Understanding of Science*. SAGE Publications Ltd, 9(4) pp. 417–431.

Au, Ryan, Carey and Whalley (1993) *Managing crowd safety in public venues: a study to generate guidance for venue owners and enforcing authority inspectors*. Health and Safety Executive.

Australian Entertainment Safety Resource Guide (2017) *Crowd Dynamics*. Australian Entertainment Safety Resource Guide. [Online] https://aesrg.com.au/chapters/crowd-dynamics/.

Azevedo, V., Carvalho, M., Costa, F., Mesquita, S., Soares, J., Teixeira, F. and Maia, Â. (2017) ‘Interview transcription: conceptual issues, practical guidelines, and challenges.’ *Revista de Enfermagem Referência*, IV Série(Nº14) pp. 159–168.

Babut, G.-B., Moraru, R.-I. and Cioca, L.-I. (2011) ‘“Kinney-type methods”: Useful of harmful tools in the risk assessment and management process?’ *In*. Sibiu: MSE, pp. 1–4.

Backer, J. A., Klinkenberg, D. and Wallinga, J. (2020) ‘Incubation period of 2019 novel coronavirus (2019-nCoV) infections among travellers from Wuhan, China, 20–28 January 2020.’ *Eurosurveillance*. European Centre for Disease Prevention and Control, 25(5) p. 2000062.

Bahl, P., Doolan, C., de Silva, C., Chughtai, A. A., Bourouiba, L. and MacIntyre, C. R. (2020) ‘Airborne or Droplet Precautions for Health Workers Treating Coronavirus Disease 2019?’ *The Journal of Infectious Diseases*, April, p. jiaa189.

Bai, Y., Yao, L., Wei, T., Tian, F., Jin, D.-Y., Chen, L. and Wang, M. (2020) ‘Presumed Asymptomatic Carrier Transmission of COVID-19.’ *JAMA*. American Medical Association, 323(14) pp. 1406–1407.

Baker, M. J. and Foy, A. (2008) *Business and management research: how to complete your research project successfully*. 2. ed, Helensburgh: Westburn.

Balsari, S., Van Vaerenewyck, L., Sistenich, V. and Leanning, J. (2017) *New Year’s Stampede: Lan Kwai Fong 1993*. Harvard: Harvard School of Public Health (FXB/DPRI Case Study Series).

Bellomo, N., Clarke, D., Gibelli, L., Townsend, P. and Vreugdenhil, B. J. (2016) ‘Human behaviours in evacuation crowd dynamics: From modelling to “big data” toward crisis management.’ *Physics of Life Reviews*, 18, September, pp. 1–21.

Berlonghi, A. E. (1993) ‘Risk Analysis for Special Events.’ *In* Smith, R. A. and Dickie, J. F. (eds) *Engineering for crowd safety: proceedings of the International Conference on Engineering for Crowd Safety, London, UK, 17-18 March, 1993*. Amsterdam ; New York: Elsevier Science Publishers, pp. 239–247.

Berlonghi, A. E. (1995) ‘Understanding and planning for different spectator crowds.’ *Safety Science* pp. 239–247.

Biggam, J. (2017) *Succeeding with Your Master’s Dissertation A step-by-step handbook*. 4th edition, London: Open University Press (Open Up Study Skills).

Block, P., Hoffman, M., Raabe, I. J., Dowd, J. B., Rahal, C., Kashyap, R. and Mills, M. C. (2020) ‘Social network-based distancing strategies to flatten the COVID-19 curve in a post-lockdown world’ p. 42.

Bogoch, I. I., Watts, A., Thomas-Bachli, A., Huber, C., Kraemer, M. U. G. and Khan, K. (2020) 'Pneumonia of unknown aetiology in Wuhan, China: potential for international spread via commercial air travel.' *Journal of Travel Medicine*. Oxford Academic, 27(2).

Bolton, K., McCaw, J., Moss, R., Morris, R., Wang, S., Burma, A., Darma, B., Narangerel, D., Nymadawa, P. and McVernon, J. (2012) 'Likely effectiveness of pharmaceutical and non-pharmaceutical interventions for mitigating influenza virus transmission in Mongolia.' *Bulletin of the World Health Organization*, 90(4) pp. 264–271.

Bonell, C., Michie, S., Reicher, S., West, R., Bear, L., Yardley, L., Curtis, V., Amlôt, R. and Rubin, G. J. (2020) 'Harnessing behavioural science in public health campaigns to maintain "social distancing" in response to the COVID-19 pandemic: key principles.' *J Epidemiol Community Health*. BMJ Publishing Group Ltd, 74(8). Commentary pp. 617–619.

Boone, S. A. and Gerba, C. P. (2007) 'Significance of Fomites in the Spread of Respiratory and Enteric Viral Disease.' *Applied and Environmental Microbiology*, 73(6) pp. 1687–1696.

Bourouiba, L. (2020) 'Turbulent Gas Clouds and Respiratory Pathogen Emissions: Potential Implications for Reducing Transmission of COVID-19.' *JAMA*, March.

Bryman, A. (2016) *Social research methods*. Fifth Edition, Oxford ; New York: Oxford University Press.

Bulgarian Government (2020) *Заповед № РД-01-403 от 15.07.2020 г. за въвеждане на противоепидемични мерки на територията на Република България (Order № RD-01-403 of 15.07.2020 for introduction of anti-epidemic measures on the territory of the Republic of Bulgaria)*. Unified Information Portal. [Online] [Accessed on 25th July 2020] https://coronavirus.bg/bg/471.

Canter, D., Breaux, J. and Sime, J. D. (1990) 'Domestic, multiple occupancy and hospital fires.' *In Fires and Human Behaviour*. 2nd edition, London: David Fulton Publishers, pp. 117–136.

Carducci, A., Federigi, I. and Verani, M. (2020) 'Covid-19 Airborne Transmission and Its Prevention: Waiting for Evidence or Applying the Precautionary Principle?' *Atmosphere*. Multidisciplinary Digital Publishing Institute, 11(7) p. 710.

CDC (2020) *Coronavirus disease 2019 (COVID-19)*. Centers for Disease Control and Prevention. [Online] [Accessed on 11th April 2020] https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/social-distancing.html.

Cepolina, E. M. (2005) 'A methodology for defining building evacuation routes.' *Civil Engineering and Environmental Systems*, 22(1) pp. 29–47.

Challenger, R. (2011) 'Understanding Crowd Behaviours: A Systems Perspective.'

Challenger, R. and Clegg, C. W. (2011) 'Crowd disasters: a socio-technical systems perspective.' *Contemporary Social Science*, 6(3) pp. 343–360.

Challenger, R., Clegg, C. W. and Robinson, M. (2010a) *Understanding crowd behaviours Volume 1 - Practical Guidance and Lessons Learned*. London: TSO.

Challenger, R., Clegg, C. W. and Robinson, M. (2010b) *Understanding crowd behaviours Volume 2 – Supporting Theory and Evidence*. London: TSO.

Chen, J. (2020) 'Pathogenicity and transmissibility of 2019-nCoV—A quick overview and comparison with other emerging viruses.' *Microbes and Infection*. (Special issue on the new coronavirus causing the COVID-19 outbreak), 22(2) pp. 69–71.

Chen, N., Zhou, M., Dong, X., Qu, J., Gong, F., Han, Y., Qiu, Y., Wang, J., Liu, Y., Wei, Y., Xia, J., Yu, T., Zhang, X. and Zhang, L. (2020) 'Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study.' *The Lancet*, 395(10223) pp. 507–513.

Chin, K. (2020) 'Coronavirus Fallout: A Roundup of Canceled Events.' *Wall Street Journal*. Business. [Online] 13th March. [Accessed on 23rd November 2020] https://www.wsj.com/articles/coronavirus-fallout-a-roundup-of-canceled-events-11583943224.

Citizensinformation.ie (2020) *COVID-19: What you need to do*. Citizensinformation.ie. [Online] [Accessed on 27th July 2020] https://www.citizensinformation.ie/en/health/covid19/covid19_what_you_need_to_do.html.

Clarke, L. (2002) 'Panic: Myth or Reality?' *Contexts*, 1(3) pp. 21–26.

Cocking, C. (2016) 'Brussels terror attack victims show how humans help each other in times of crisis.' The Conversation. [Online] [Accessed on 5th May 2019] http://theconversation.com/brussels-terror-attack-victims-show-how-humans-help-each-other-in-times-of-crisis-56707.

Cocking, C. and Drury, J. (2008) 'The mass psychology of disasters and emergency evacuations: A research report and implications for the Fire and Rescue Service.' *Fire Safety,Technology and Management*, 10 pp. 13–19.

Cocking, C. and Drury, J. (2014) 'Talking about Hillsborough: "Panic" as Discourse in Survivors' Accounts of the 1989 Football Stadium Disaster: Talking about Hillsborough.' *Journal of Community & Applied Social Psychology*, 24(2) pp. 86–99.

Coleman, M. E. and Marks, H. M. (1999) 'Qualitative and quantitative risk assessment.' *Food Control* p. 9.

Comeau, E. and Duval, R. F. (2000) *Dance Hall Fire Gothenburg Sweden*. Quincy: National Fire Protection Association, p. 41.

Cosio, M. Q. and Taylor, G. W. (1992) 'Soda Pop Vending Machine Injuries: An Update.' *Journal of Orthopaedic Trauma*, 6(2) pp. 186–189.

Cowling, B. J., Ali, S. T., Ng, T. W. Y., Tsang, T. K., Li, J. C. M., Fong, M. W., Liao, Q., Kwan, M. Y., Lee, S. L., Chiu, S. S., Wu, J. T., Wu, P. and Leung, G. M. (2020) 'Impact assessment of non-pharmaceutical interventions against coronavirus disease 2019 and influenza in Hong Kong: an observational study.' *The Lancet Public Health*. Elsevier, 5(5) pp. e279–e288.

Cresswell, S. (2013) 'Qualitative Risk Assessment & Probability Impact Graphs, time for a rethink?' Into Risk.

Croatian Institute of public health (2020) *What to expect in Croatia - important information for visitors*. koronavirus.hr. [Online] [Accessed on 27th July 2020] https://www.koronavirus.hr/what-to-expect-in-croatia-important-information-for-visitors/624.

Crosby, L. and Crosby, E. (2020) 'Applying the precautionary principle to personal protective equipment (PPE) guidance during the COVID-19 pandemic: did we learn the lessons of SARS?' *Canadian Journal of Anesthesia/Journal canadien d'anesthésie*, July.

Crowe, J. E. (2008) 'Human Respiratory Viruses.' *In* Mahy, B. W. J. and Van Regenmortel, M. H. V. (eds) *Encyclopedia of Virology (Third Edition)*. Oxford: Academic Press, pp. 551–558.

Cypriotic Minister of Health (2020) ‘Minister of Health to issue new decree under the Quarantine Law Act.’ Ministery of Health.

Danish Health Authority (2020) *Protect yourself and others: Coronavirus/COVID-19*. Coronavirus/COVID-19. [Online] [Accessed on 25th July 2020] https://www.sst.dk/en/english/corona-eng.

Darley, J. M. and Latane, B. (1968) ‘Bystander intervention in emergencies.’ *Journal of Personality and Social Psychology*, 8(4) pp. 377–383.

Davis & Associates (2003) *Operations: Managing Large Events and Perturbations at Stations, Literature Review*. London: Rail Safety and Standards Board.

Dean, J. (2009) ‘7 Myths of Crowd Psychology.’ PsyBlog. [Online] [Accessed on 5th July 2019] http://www.spring.org.uk/2008/08/7-myths-of-crowd-psychology.php.

Denscombe, M. (2010) *The good research guide for small-scale social research projects*. 4th ed., Maidenhead, England: McGraw-Hill/Open University Press.

Denscombe, M. (2014) *The Good Research Guide*. 5th Edition, London: Open University Press (Open Up Study Skills).

Dickie, J. F. (1995) ‘Major crowd catastrophes.’ *Safety Science*, 18(4) pp. 309–320.

Dillen, J. (2009) ‘Stop met het gebruik van de methode van Kinney als kwantitatieve risicoevaluatiemethode.’ *Prevent Focus*.

Donald, I. and Canter, D. (1992) ‘Intentionality and fatality during the King’s Cross underground fire.’ *European Journal of Social Psychology*, 22(3) pp. 203–218.

van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., Tamin, A., Harcourt, J. L., Thornburg, N. J., Gerber, S. I., Lloyd-Smith, J. O., de Wit, E. and Munster, V. J. (2020) ‘Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1.’ *New England Journal of Medicine*. Massachusetts Medical Society, 382(16) pp. 1564–1567.

Dridi, M. H. (2015) ‘List of Parameters Influencing the Pedestrian Movement and Pedestrian Database.’ *International Journal of Social Science Studies*, 3(4) pp. 93–105.

Drintewater, J. A. and Gudjonson, G. (1989) ‘The Nature of Violence in Psychiatric Hospitals.’ *In* Howell, K. and Hollin, S. (eds) *Clinical Approaches to Violence*. Chichester: John Wiley & Sons Inc.

Drury, J. (2003) ‘Social Identity as a Source of Strength in Mass Emergencies and Other Crowd Events.’ *International Journal of Mental Health*. Routledge, 32(4) pp. 77–93.

Drury, J. (2011) ‘What do the events of 9-11 tell us.’ The Crowd. 9th November. [Online] [Accessed on 5th July 2019] http://drury-sussex-the-crowd.blogspot.be/2011/09/what-do-events-of-9-11-tell-us.html.

Drury, J., Carter, H., Cocking, C., Ntontis, E., Tekin Guven, S. and Amlôt, R. (2019) ‘Facilitating Collective Psychosocial Resilience in the Public in Emergencies: Twelve Recommendations Based on the Social Identity Approach.’ *Frontiers in Public Health*, 7.

Drury, J. and Cocking, C. (2007) *The mass psychology of disasters and emergency evacuations: A research report and implications for the Fire and Rescue Service. Unpublished manuscript*. University of Sussex.

Drury, J., Cocking, C. and Reicher, S. (2009) 'The Nature of Collective Resilience: Survivor Reactions to the 2005 London Bombings.' *International Journal of Mass Emergencies and Disasters*, 27(1) pp. 66–95.

Drury, J., Novelli, D. and Stott, C. (2015) 'Managing to avert disaster: Explaining collective resilience at an outdoor music event: Collective resilience at an outdoor music event.' *European Journal of Social Psychology*, 45(4) pp. 533–547.

Drury, J. and Reicher, S. (1999) 'The Intergroup Dynamics of Collective Empowerment: Substantiating the Social Identity Model of Crowd Behavior.' *Group Processes & Intergroup Relations*, 2(4) pp. 381–402.

Drury, J. and Reicher, S. D. (2010) 'Crowd Control.' *Scientific American Mind*, 21(5) pp. 58–65.

Drury, J. and Stott, C. (2011) 'Contextualising the crowd in contemporary social science.' *Contemporary Social Science*, 6(3) pp. 275–288.

Drury, P. J. (2020) 'the crowd: Mitigating the new variant SARS-CoV-2 virus: How to support public adherence to physical distancing.' the crowd. 24th December. [Online] [Accessed on 29th December 2020] http://drury-sussex-the-crowd.blogspot.com/2020/12/mitigating-new-variant-sars-cov-2-virus.html.

Duijm, N. J. (2015) 'Recommendations on the use and design of risk matrices.' *Safety Science*, 76, July, pp. 21–31.

Duives, D. C., Daamen, W. and Hoogendoorn, S. P. (2013) 'State-of-the-art crowd motion simulation models.' *Transportation Research Part C: Emerging Technologies*, 37, December, pp. 193–209.

van Duykeren, G. (2012) *Crowd Management & Risico Analyse*. Utrecht: TSC Academy.

Earl, C. (2008) 'Crowds at Outdoor Music Festivals: An Examination of Crowd Psychology and its Implications for the Environmental Health Practitioner.' *Environmental Health*, 34–43(1) p. 10.

Earl, C., Parker, E. and Capra, M. (2005) 'The Management of Crowds and Other Risks at Outdoor Music Festivals: A Review of the Literature.' *Environmental Health*, 5(1) pp. 37–49.

Elcheroth, G. and Drury, J. (2020) 'Collective resilience in times of crisis: Lessons from the literature for socially effective responses to the pandemic.' *British Journal of Social Psychology*, 59(3) pp. 703–713.

Elliott, D. and Smith, D. (1993) 'Football stadia disasters in the United Kingdom: learning from tragedy?' *Industrial & Environmental Crisis Quarterly*, 7(3) pp. 205–229.

Elms, D. G. (1992) 'Risk Balancing Approaches.' *In* Topping, B. H. V. (ed.) *Optimization and Artificial Intelligence in Civil and Structural Engineering: Volume I: Optimization in Civil and Structural Engineering*. Dordrecht: Springer Netherlands (NATO ASI Series), pp. 61–70.

Escher, R. A. (2020) 'An Ounce of Prevention: Coronavirus (COVID-19) and Mass Gatherings.' *Cureus*, 12(3).

ESI (2020) 'Basisnormen crowdmanagement voor de openbare ruimte en publieksevenementen in de 1,5 metersamenleving.' Event Safety Institute.

Estonian Government (2020) *Ten most important things to know about the coronavirus and its prevention*. Government of the Republic of Estonia. [Online] [Accessed on 25th July 2020] https://www.kriis.ee/en?

European Centre for Disease Prevention (2020) 'Coronavirus disease 2019 (COVID-19) pandemic: increased transmission in the EU/EEA and the UK – seventh update.' ECDC.

Evans, E. and Hayden, F. (1971) 'Test on live subjects to determine the tolerable forces that may be exerted by crowd control crush barriers.' *In* Smith, R. A. and Dickie, J. F. (eds) *Report on Research in Biomechanics at the University of Surrey*. Guildford UK: University of Surrey.

Event Safety Alliance (2020) 'ANSI+ES1.9-2020 Crowd Management.' ANSI.

Fahy, R. F., Proulx, G. and Aiman, L. (2009) '"Panic" and human behaviour in fire.' *In Proceedings of the 4th International Symposium on Human Behaviour in Fire*. Cambridge: National Research Council, pp. 387–398.

Farenc, N., Musse, S. R., Schweiss, E., Kallmann, M., Aune, O., Boulic, R. and Thalmann, D. (2000) 'A paradigm for controlling virtual humans in urban environment simulations.' *Applied Artificial Intelligence*, 14(1) pp. 69–91.

Fattal, S. G. and Cattaneo, L. E. (1976) *Investigation of Guardrails for the Protection of Employees from Occupational Hazards*. Washington, DC, USA: Occupational Safety and Health Administration Department of Labor, p. 126.

Federal Ministry of the Interior, Building and Community (2020) *Coronavirus: Frequently Asked Questions*. Federal Ministry of the Interior, Building and Community. [Online] [Accessed on 28th July 2020] http://www.bmi.bund.de/SharedDocs/faqs/EN/topics/civil-protection/coronavirus/coronavirus-faqs.html?nn=9385444.

Federal Ministry Republic of Austria (2020) *Coronavirus Austria*. Coronavirus. [Online] [Accessed on 12th April 2020] https://www.sozialministerium.at/en/Coronavirus.html.

Fell, A. (2003) 'A Study of Modeling Crowd Dynamics' p. 33.

Feng, S., Shen, C., Xia, N., Song, W., Fan, M. and Cowling, B. J. (2020) 'Rational use of face masks in the COVID-19 pandemic.' *The Lancet Respiratory Medicine*. Elsevier, 8(5) pp. 434–436.

Ferguson, N. M., Cummings, D. A. T., Fraser, C., Cajka, J. C., Cooley, P. C. and Burke, D. S. (2006) 'Strategies for mitigating an influenza pandemic.' *Nature*. Nature Publishing Group, 442(7101) pp. 448–452.

Fernstrom, A. and Goldblatt, M. (2013) 'Aerobiology and Its Role in the Transmission of Infectious Diseases.' *Journal of Pathogens*, 2013 pp. 1–13.

Festinger, L., Pepitone, A. and Newcomb, T. (1952) 'Some consequences of de-individuation in a group.' *Journal of Abnormal and Social Psychology*, 48 pp. 382–389.

Finnish Institute for health and welfare (2020) *Transmission and protection – coronavirus - Infectious diseases and vaccinations - THL*. Finnish Institute for Health and Welfare (THL), Finland. [Online] [Accessed on 25th July 2020] https://thl.fi/en/web/infectious-diseases-and-vaccinations/what-s-new/coronavirus-covid-19-latest-updates/transmission-and-protection-coronavirus.

Fischer, H. W. (2002) ‘Terrorism and 11 September 2001: does the “behavioral response to disaster” model fit?’ *Disaster Prevention and Management: An International Journal*, 11(2) pp. 123–127.

Flaxman, S., Mishra, S., Gandy, A., Unwin, H. J. T., Mellan, T. A., Coupland, H., Whittaker, C., Zhu, H., Berah, T., Eaton, J. W., Monod, M., Imperial College COVID-19 Response Team, Ghani, A. C., Donnelly, C. A., Riley, S., Vollmer, M. A. C., Ferguson, N. M., Okell, L. C. and Bhatt, S. (2020) ‘Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe.’ *Nature*, 584(7820) pp. 257–261.

FOD Binnenlandse Zaken (2020a) *Ministerieel besluit houdende dringende maatregelen om de verspreiding van het coronavirus COVID - 19 te beperken (18 maart 2020)*.

FOD Binnenlandse Zaken (2020b) *Ministerieel besluit houdende wijziging van het ministerieel besluit van 28 oktober 2020 houdende dringende maatregelen om de verspreiding van het coronavirus COVID-19 te beperken (20 december 2020)*.

Frankopan, P. (2020) *Past pandemics exacerbated disadvantages – what we can learn from them about the coronavirus recovery*. The Conversation. [Online] [Accessed on 25th March 2021] http://theconversation.com/past-pandemics-exacerbated-disadvantages-what-we-can-learn-from-them-about-the-coronavirus-recovery-141254.

Fruin, J. J. (1971) ‘Designing for Pedestrians: A Level of Service Concept.’ *In*. Washington DC: Highway Research Board.

Fruin, J. J. (1984) ‘Crowd Dynamics and Auditorium Management.’ *Auditorium News*.

Fruin, J. J. (1987) *Pedestrian planning and design*. Alabama: Elevator World.

Fruin, J. J. (1993) ‘The causes and prevention of crowd disasters.’ *In* Smith, R. A. and Dickie, J. F. (eds) *Engineering for crowd safety: proceedings of the International Conference on Engineering for Crowd Safety, London, UK, 17-18 March, 1993*. Amsterdam ; New York: Elsevier, pp. 99–108.

Gantt, P. and Gantt, R. (2012) ‘Disaster Psychology: Dispelling the Myths of Panic.’ *Professional Safety*. American Society of Safety Engineers, 57(08) pp. 42–49.

Ganyani, T., Kremer, C., Chen, D., Torneri, A., Faes, C., Wallinga, J. and Hens, N. (2020) ‘Estimating the generation interval for COVID-19 based on symptom onset data.’ *medRxiv*. Cold Spring Harbor Laboratory Press, March, p. 2020.03.05.20031815.

Gao, M., Yang, L., Chen, X., Deng, Y., Yang, S., Xu, H., Chen, Z. and Gao, X. (2020) ‘A study on infectivity of asymptomatic SARS-CoV-2 carriers.’ *Respiratory Medicine*, 169, August, p. 106026.

Garcia, S. E., Mzezewa, T., Vigdor, N., Zaveri, M., Zraick, K., Sisario, B., Anderson, M. and Padilla, M. (2020) ‘A List of What’s Been Canceled Because of the Coronavirus.’ *The New York Times*. World. [Online] 1st April. [Accessed on 23rd November 2020] https://www.nytimes.com/article/cancelled-events-coronavirus.html.

Gayathri, H., Aparna, P. M. and Verma, A. (2017) ‘A review of studies on understanding crowd dynamics in the context of crowd safety in mass religious gatherings.’ *International Journal of Disaster Risk Reduction*, 25, October, pp. 82–91.

Germann, T. C., Kadau, K., Longini, I. M. and Macken, C. A. (2006) ‘Mitigation strategies for pandemic influenza in the United States.’ *Proceedings of the National Academy of Sciences*, 103(15) pp. 5935–5940.

Glass, R. J., Glass, L. M., Beyeler, W. E. and Min, H. J. (2006) 'Targeted Social Distancing Design for Pandemic Influenza.' *Emerging Infectious Diseases*, 12(11) p. 11.

Goldberg, S. A., Pu, C. T., Thompson, R. W., Mark, E., Sequist, T. D. and Grabowski, D. C. (2020) 'Asymptomatic Spread of COVID-19 in 97 Patients at a Skilled Nursing Facility.' *Journal of the American Medical Directors Association*, 21(7) pp. 980–981.

Goldman, E. (2020) 'Exaggerated risk of transmission of COVID-19 by fomites.' *The Lancet Infectious Diseases*. Elsevier, 20(8) pp. 892–893.

Gorbalenya, A. E., Baker, S. C., Baric, R. S., Groot, R. J. de, Drosten, C., Gulyaeva, A. A., Haagmans, B. L., Lauber, C., Leontovich, A. M., Neuman, B. W., Penzar, D., Perlman, S., Poon, L. L. M., Samborskiy, D., Sidorov, I. A., Sola, I. and Ziebuhr, J. (2020) 'Severe acute respiratory syndrome-related coronavirus: The species and its viruses – a statement of the Coronavirus Study Group.' *bioRxiv*. Cold Spring Harbor Laboratory, February,. New Results p. 2020.02.07.937862.

Gorbunov, B. (2020) 'Aerosol Particles Laden with Viruses That Cause COVID-19 Travel Over 30m Distance.' Preprints, May.

Government Communication Office (2020) *Coronavirus disease COVID-19 | GOV.SI*. Portal GOV.SI. [Online] [Accessed on 28th July 2020] https://www.gov.si/en/topics/coronavirus-disease-covid-19/.

Government of Canada, C. C. for O. H. and S. (2019) *Hazard and Risk : OSH Answers*. [Online] [Accessed on 13th August 2019] http://www.ccohs.ca/.

Government of Malta (2020) *Protecting Yourself*. [Online] [Accessed on 27th July 2020] https://deputyprimeminister.gov.mt/en/health-promotion/covid-19/Pages/protecting-yourself.aspx.

Government of the Czech Republic (2020) *Measures adopted by the Czech Government against the coronavirus | Government of the Czech Republic*. Measures adopted by the Czech Government against the coronavirus. [Online] [Accessed on 28th July 2020] https://www.vlada.cz/en/media-centrum/aktualne/measures-adopted-by-the-czech-government-against-coronavirus-180545/.

Gray, D. E. (2018) *Doing research in the real world*. 4th ed., Los Angeles: SAGE Publications Ltd.

Greenhalgh, T., Schmid, M. B., Czypionka, T., Bassler, D. and Gruer, L. (2020) 'Face masks for the public during the covid-19 crisis.' *BMJ*, April, p. m1435.

Greenstone, M. and Nigam, V. (2020) 'Does Social Distancing Matter?' *SSRN Electronic Journal*.

Grupul de Comunicare Strategică de Romania (2020) *15 RECOMANDĂRI privind conduita socială responsabilă în prevenirea răspândirii coronavirus (COVID-19)*. [Online] [Accessed on 27th July 2020] https://gov.ro/fisiere/pagini_fisiere/11_martie_-_15_RECOMAND%C4%82RI_privind_conduita_social%C4%83_responsabil%C4%83_%C3%AEn_prevenirea_r%C4%83sp%C3%A2ndirii_coronavirus_(COVID-19).pdf.

Gwynne, S., Galea, E. R., Owen, M., Lawrence, P. J. and Filippidis, L. (1999) 'A review of the methodologies used in the computer simulation of evacuation from the built environment.' *Building and Environment*, 34(6) pp. 741–749.

Gwynne, S. M. V. and Boyce, K. E. (2016) 'Engineering Data.' *In* Hurley, M. J., Gottuk, D., Hall, J. R., Harada, K., Kuligowski, E., Puchovsky, M., Torero, J., Watts, J. M., and Wieczorek, C. (eds) *SFPE Handbook of Fire Protection Engineering*. New York, NY: Springer New York, pp. 2429–2551.

Haghe, L. (1854) *Funeral of the Duke of Wellington. The funeral car passing the archway at Apsley House, London, 18th November 1852*.

Hales, T. (2000) 'The Honeycomb Conjecture.' *Discr. Comput. Geom.*, 25, April.

Hall (1974) *Handbook for proxemic research*. Washington, D.C: Society for the anthropology of visual communication.

Harding, P. J., Gwynne, S. M. V. and Amos, M. (2010) 'An early warning method for crush.' *arXiv:1008.2160 [cs]*, August.

Helbing, D., Buzna, L. and Werner, T. (2005) 'Self-Organized Pedestrian Crowd Dynamics and Design Solutions.' *Transportation Science*, 39 pp. 1–24.

Helbing, D. and Mukerji, P. (2012) 'Crowd disasters as systemic failures: analysis of the Love Parade disaster.' *EPJ Data Science*, 1(1) p. 7.

Herling, R. W. (2000) 'Operational Definitions of Expertise and Competence.' *Advances in Developing Human Resources*. SAGE Publications, 2(1) pp. 8–21.

Holton, R. J. (1978) 'The crowd in history: Some problems of theory and method.' *Social History*, 3(2) pp. 219–233.

Hopkins, I. H. G., Poutney, S., Hayes, P. and Sheppard, M. (1993) 'Crowd Pressure Monitoring.' *In Engineering for Crod Safety*. Amsterdam - New York: Elsevier, pp. 389–398.

Hoskins, B. L. (2011) *The effects of interactions and individual characteristics on egress down stairs*. PhD. University of Maryland.

Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., Zhang, L., Fan, G., Xu, J., Gu, X., Cheng, Z., Yu, T., Xia, J., Wei, Y., Wu, W., Xie, X., Yin, W., Li, H., Liu, M., Xiao, Y., Gao, H., Guo, L., Xie, J., Wang, G., Jiang, R., Gao, Z., Jin, Q., Wang, J. and Cao, B. (2020) 'Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China.' *The Lancet*, 395(10223) pp. 497–506.

Hubbard, D. (2009) *The Failure of Risk Management: Why It's Broken and How to Fix it.* New Jersey: John Wiley & Sons Inc.

Hui, D. S., I Azhar, E., Madani, T. A., Ntoumi, F., Kock, R., Dar, O., Ippolito, G., Mchugh, T. D., Memish, Z. A., Drosten, C., Zumla, A. and Petersen, E. (2020) 'The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health — The latest 2019 novel coronavirus outbreak in Wuhan, China.' *International Journal of Infectious Diseases*, 91, February, pp. 264–266.

INCONTROL Simulation Solutions (2020) *Social Distancing in Pedestrian Dynamics - Simulation*. [Online] [Accessed on 6th January 2021] https://www.youtube.com/watch?v=ENx68G8fXHw.

Jefferson, T., Jones, M., Ansari, L. A. A., Bawazeer, G., Beller, E., Clark, J., Conly, J., Mar, C. D., Dooley, E., Ferroni, E., Glasziou, P., Hoffman, T., Thorning, S. and Driel, M. V. (2020) 'Physical interventions to interrupt or reduce the spread of respiratory viruses. Part 1 - Face

masks, eye protection and person distancing: systematic review and meta-analysis.' *medRxiv*. Cold Spring Harbor Laboratory Press, April, p. 2020.03.30.20047217.

Jetten, J., Reicher, S., Haslam, S. A. and Cruwys, T. (2020) *Together apart: the psychology of COVID-19*.

Johansson, A., Helbing, D., Al-Abideen, H. Z. and Al-Bosta, S. (2008) 'From crowd dynamics to crowd safety: a video-based analysis.' *Advances in Complex Systems*, 11(04) pp. 497–527.

Johnson, G. R., Morawska, L., Ristovski, Z. D., Hargreaves, M., Mengersen, K., Chao, C. Y. H., Wan, M. P., Li, Y., Xie, X., Katoshevski, D. and Corbett, S. (2011) 'Modality of human expired aerosol size distributions.' *Journal of Aerosol Science*, 42(12) pp. 839–851.

Johnson, N. R. (1988) 'Fire in a crowded theatre: a descriptive investigation of the emergence of panic.' *International Journal of Mass Emergencies and Disasters*, 6(1) pp. 7–26.

Kang, D. and Choi, B. K. (2010) 'Visual Modeling And Simulation Toolkit For Activity Cycle Diagram.' *In Proceedings 24th European Conference on Modelling and Simulation*.

Kaplan, S. (1997) 'The Words of Risk Analysis.' *Risk Analysis*, 17(4) pp. 407–417.

Kaplan, S. and Garrick, B. J. (1981) 'On The Quantitative Definition of Risk.' *Risk Analysis*, 1(1) pp. 11–27.

Kelemen, M. and Rumens, N. (2008) *An Introduction to Critical Management Research*. 1 Oliver's Yard, 55 City Road, London England EC1Y 1SP United Kingdom: SAGE Publications, Ltd.

Kemp, C., Hil, I. and Upton, M. (2004) *A comparative study of crowd behaviour at two major music events*. Cambridge: Entertainment Technology Press.

Kendrick, V. (2013) *The user experience of crowds*. PhD. Loughborough University.

Kinney, G. F. and Wiruth, A. D. (1976) *Practical Risk Analysis for Safety Management*. China Lake: Naval Weapons Center, p. 27.

Klüpfel, H. (2007) 'The simulation of crowd dynamics at very large events — Calibration, empirical data, and validation.' *In* Waldau, N., Gattermann, P., Knoflacher, H., and Schreckenberg, M. (eds) *Pedestrian and Evacuation Dynamics 2005*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 285–296.

Klüpfel, H., Schreckenberg, M. and Meyer-Konig, T. (2003) 'Models for Crowd Movement and Egress Simulation' p. 16.

Kroll, M. W., Still, G. K., Neuman, T. S., Graham, M. A. and Griffin, L. V. (2017) 'Acute forces required for fatal compression asphyxia: A biomechanical model and historical comparisons.' *Medicine, Science and the Law*, 57(2) pp. 61–68.

Kuligowski, E. D. (2008) *Modeling Human Behavior during Building Fires*. National Institute of Standards and Technology, p. 22.

Kuligowski, E. D. and Gwynne, S. M. V. (2005) 'What a user Should Know When Selecting an Evacuation Model.' *Fire Protection Engineering* p. 9.

Kuligowski, E. D. and Peacock, R. D. (2005) *A review of building evacuation models*. Gaithersburg, MD: National Bureau of Standards, p. NBS TN 1471.

Kuligowski, E. D., Richard Peacock and Hoskins, B. L. (2010) *A Review of Building Evacuation Models: 2nd Edition*. Gaithersburg, Maryland: National Institute of Standards and Technology, p. 36.

Kumar, R. (2018) *Research methodology: a step-by-step guide for beginners*. 5th edition, Thousand Oaks, CA: SAGE Publications.

Kutter, J. S., Spronken, M. I., Fraaij, P. L., Fouchier, R. A. and Herfst, S. (2018) 'Transmission routes of respiratory viruses among humans.' *Current Opinion in Virology*. (Emerging viruses: intraspecies transmission • Viral Immunology), 28, February, pp. 142–151.

Lai, C.-C., Shih, T.-P., Ko, W.-C., Tang, H.-J. and Hsueh, P.-R. (2020) 'Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): The epidemic and the challenges.' *International Journal of Antimicrobial Agents*, 55(3) p. 105924.

Latvijas Republikas Veselības ministrija (2020) *Novel Coronavirus COVID-19 advice for the public - Latvijas Republikas Veselības ministrija*. [Online] [Accessed on 27th July 2020] https://www.vm.gov.lv/en/ministry/novel_coronavirus_covid19_advice_for_the_public1/.

Lauer, S. A., Grantz, K. H., Bi, Q., Jones, F. K., Zheng, Q., Meredith, H. R., Azman, A. S., Reich, N. G. and Lessler, J. (2020) 'The Incubation Period of Coronavirus Disease 2019 (COVID-19) From Publicly Reported Confirmed Cases: Estimation and Application.' *Annals of Internal Medicine*. American College of Physicians, 172(9) pp. 577–582.

Le Bon, G. (1895) *Psychologie des Foules*. Paris: Alcan.

Leary, R. and Kershaw, J. A. Jr. (2014) 'Tips for Conducting an Effective Literature Review.'

Lee, R. S. C. and Hughes, R. L. (2006) 'Prediction of human crowd pressures.' *Accident Analysis & Prevention*, 38(4) pp. 712–722.

Lee, R. S. C. and Hughes, R. L. (2007) 'Minimisation of the risk of trampling in a crowd.' *Mathematics and Computers in Simulation*, 74(1) pp. 29–37.

Lee, R. S. and Hughes, R. L. (2005) 'Exploring Trampling and Crushing in a Crowd.' *Journal of Transportation Engineering*, 131(8) pp. 575–582.

Lewis, R. (2020) *Coronavirus Stays in Aerosols for Hours, on Surfaces for Days*. Medscape. [Online] www.medscape.com.

Lewnard, J. A. and Lo, N. C. (2020) 'Scientific and ethical basis for social-distancing interventions against COVID-19.' *The Lancet. Infectious Diseases*, 20(6) pp. 631–633.

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., Ren, R., Leung, K. S. M., Lau, E. H. Y., Wong, J. Y., Xing, X., Xiang, N., Wu, Y., Li, C., Chen, Q., Li, D., Liu, T., Zhao, J., Liu, M., Tu, W., Chen, C., Jin, L., Yang, R., Wang, Q., Zhou, S., Wang, R., Liu, H., Luo, Y., Liu, Y., Shao, G., Li, H., Tao, Z., Yang, Y., Deng, Z., Liu, B., Ma, Z., Zhang, Y., Shi, G., Lam, T. T. Y., Wu, J. T., Gao, G. F., Cowling, B. J., Yang, B., Leung, G. M. and Feng, Z. (2020) 'Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus–Infected Pneumonia.' *New England Journal of Medicine*. Massachusetts Medical Society, January.

Li, R., Pei, S., Chen, B., Song, Y., Zhang, T., Yang, W. and Shaman, J. (2020) 'Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV-2).' *Science*, 368(6490) pp. 489–493.

Li, X., Song, W., Xu, X., Zhang, J., Xia, L. and Shi, C. (2020) 'Experimental study on pedestrian contact force under different degrees of crowding.' *Safety Science*, 127, July, p. 104713.

Li, X., Zhou, J., Chen, F. and Zhang, Z. (2018) 'Cluster Risk of Walking Scenarios Based on Macroscopic Flow Model and Crowding Force Analysis.' *Sustainability*. Multidisciplinary Digital Publishing Institute, 10(2) p. 385.

Lin, P., Ma, J., Si, Y.-L., Wu, F.-Y., Wang, G.-Y. and Wang, J.-Y. (2017) 'A numerical study of contact force in competitive evacuation.' *Chinese Physics B*, 26(10) p. 104501.

Lithuanian Government (2020) *Quarantine lifted, but some restrictions remain in place*. [Online] [Accessed on 27th July 2020] http://lrv.lt/en/news/quarantine-lifted-but-some-restrictions-remain-in-place.

Liu, Y., Gayle, A. A., Wilder-Smith, A. and Rocklöv, J. (2020) 'The reproductive number of COVID-19 is higher compared to SARS coronavirus.' *Journal of Travel Medicine*. Oxford Academic, 27(2).

Lomas, K. and Cornell, T. (eds) (2005) *Bread and Circuses*. London - New-York: Routledge.

Lovas, G. (1994) 'Modeling and simulation of pedestrian traffic flow.' *Transport Research*, 28(6) pp. 429–443.

Lu, H., Stratton, C. W. and Tang, Y.-W. (2020) 'Outbreak of pneumonia of unknown etiology in Wuhan, China: The mystery and the miracle.' *Journal of Medical Virology*, 92(4) pp. 401–402.

Lyon, A. (1967) 'Causality.pdf.' *The British Journal for the Philosophy of Science*, 1!(1) pp. 1–20.

Mahase, E. (2020) 'Covid-19: What is the R number?' *British Medical Journal*. British Medical Journal Publishing Group, 369, May,. News p. m1891.

Malchaire, J. and Koob, J.-P. (2006) 'Fiabilite de la methode Kinney d'analyse des risques.' *Médecin de Travail et Ergonomie*, 43(1) pp. 3–8.

Manning, R., Levine, M. and Collins, A. (2007) 'The Kitty Genovese murder and the social psychology of helping: The parable of the 38 witnesses.' *American Psychologist*, 62(6) pp. 555–562.

Mariel, M. and Arthur, L. (2013) 'Emergent Norm Theory.' Snow, D. A., della Porta, B., Klandermans, B., and McAdams, D. (eds) *The Wiley-Blackwell Encyclopedia of Social and Political Movements*. Blackwell Publishers Ltd.

Marshall, C. and Rossman, G. B. (2016) *Designing qualitative research*. Sixth edition, Los Angeles, California: SAGE.

McCloskey, B., Zumla, A., Ippolito, G., Blumberg, L., Arbon, P., Cicero, A., Endericks, T., Lim, P. L. and Borodina, M. (2020) 'Mass gathering events and reducing further global spread of COVID-19: a political and public health dilemma.' *The Lancet*, 395(10230) pp. 1096–1099.

McPhail, C. (1989) 'Blumer's Theory of Collective Behavior: The Development of a Non-Symbolic Interaction Explanation.' *The Sociological Quarterly*, 30(3) pp. 401–423.

McPhail, C. (1991) *The Myth of the Madding Crowd*. New York: Aldine de Gruyter.

Memish, Z. A., Ahmed, Q. A., Schlagenhauf, P., Doumbia, S. and Khan, A. (2020) 'No time for dilemma: mass gatherings must be suspended.' *The Lancet*, 395(10231) pp. 1191–1192.

Merckx, C. and Desmedt, J. (2020) 'De Belgische eventsector, meer dan feestjes en dj's alleen.' Karel de Grote Hogeschool.

Meuser, M. and Nagel, U. (2009) 'The Expert Interview and Changes in Knowledge Production.' *In* Bogner, A., Littig, B., and Menz, W. (eds) *Interviewing Experts*. London: Palgrave Macmillan UK, pp. 17–42.

Microsoft Teams | Group Chat, Team Chat & Collaboration (2021). [Online] [Accessed on 23rd March 2021] https://www.microsoft.com/en-gb/microsoft-teams/group-chat-software.

Ministère du travail de France (2020) 'Protocole national de déconfinement pour les entreprises pour assurer la santé et la sécurité des salariés.' Ministère du travail de France.

Ministerie van Algemene Zaken (2020) 'Nederlandse aanpak van het coronavirus en veelgestelde vragen - Coronavirus COVID-19 - Rijksoverheid.nl.' Rijksoverheid.

Ministerio de Sanidad (2020) *Consumo y Bienestar Social - Profesionales - Información para la ciudadanía - Coronavirus*. Información para la ciudadanía. [Online] [Accessed on 28th July 2020] https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov-China/ciudadania.htm.

Ministry of Health Portugal (2020) *COVID-19 - Página Inicial*. [Online] [Accessed on 27th July 2020] https://covid19.min-saude.pt/.

Ministry of Investments, Regional Development and Informatization of the Slovak Republic (2020) *Coronavirus (COVID-19) in the Slovak Republic*. Koronavírus a Slovensko. [Online] [Accessed on 28th July 2020] https://korona.gov.sk/en/.

Moriyama, M., Hugentobler, W. J. and Iwasaki, A. (2020) 'Seasonality of Respiratory Viral Infections.' *Annual Review of Virology*, 7(1) p. annurev-virology-012420-022445.

Motmans, R. (2005) *Volwassenen lichaamsafmetingen*. DINBelg. [Online] [Accessed on 8th November 2019] http://www.dinbelg.be/volwassenentotaal.htm.

Mumford, C., Parker, C., Ntounis, N., Lorono-Leturiondo, M. and Still, K. (2020) 'Proposing the lower bounds of area needed for individuals to social distance accros a range of town centre environments.' *Not published Version REVIEW-3*. (IPM Working Series).

National Public Health Organization (2020) *Public safety advice*. NPHO. COVID-19. [Online] [Accessed on 27th July 2020] https://eody.gov.gr/en/public-safety-advice/.

Nicoll, A., Brown, C., Karcher, F., Penttinen, P., Hegermann-Lindencrone, M., Villanueva, S., Ciotti, M., Jean-Gilles, L., Rehmet, S. and Nguyen-Van-Tam, J. S. (2012) 'Developing pandemic preparedness in Europe in the 21st century: experience, evolution and next steps.' *Bulletin of the World Health Organization*, 90(4) pp. 311–317.

Nogami, T. (2018) 'What Behaviors We Think We Do When a Disaster Strikes: Misconceptions and Realities of Human Disaster Behavior.' *In Integrating Disaster Science and Management*. Elsevier, pp. 343–362.

Oberhagemann, D. (2012) *Static and Dynamic Crowd Densities at Major Public Events*. Altenberge: Technisch-Wissenschaftlicher Beirat (TWB) der Vereinigung zur Förderung des Deutschen Brandschutzes e.V.

Pan, X., Chen, D., Xia, Y., Wu, X., Li, T., Ou, X., Zhou, L. and Liu, J. (2020) 'Asymptomatic cases in a family cluster with SARS-CoV-2 infection.' *The Lancet Infectious Diseases*. Elsevier, 20(4) pp. 410–411.

Park, R. E. (1967) *On Social Control and Collective Behavior: Selected Papers*. Chicago: University of Chicago Press.

Park, R. E. and Burghes, E. W. (1921) *Introduction to the science of sociology*. Chicago: University of Chicago Press.

Patel, P., Sanghvi, S., Malik, K. and Khachemoune, A. (2020) 'Back to the basics: Diluted bleach for COVID-19.' *Journal of the American Academy of Dermatology*, 83(1) pp. 279–280.

Pauls, J. (1984) 'The movement of people in buildings and design solutions for means of egress.' *Fire Technology*, 20(1) pp. 27–47.

Pearl, T. H. (2015) 'Crowd Crush: How the Law Leaves American Crowds Unprotected.' *SSRN Electronic Journal*.

Petrosillo, N., Viceconte, G., Ergonul, O., Ippolito, G. and Petersen, E. (2020) 'COVID-19, SARS and MERS: are they closely related?' *Clinical Microbiology and Infection*, 26(6) pp. 729–734.

Pica, N. and Bouvier, N. M. (2012) 'Environmental factors affecting the transmission of respiratory viruses.' *Current Opinion in Virology*. (Virus entry/Environmental virology), 2(1) pp. 90–95.

Pin, S. C., Haron, F., Sarmady, S., Talib, A. Z. and Khader, A. T. (2011) 'Applying TRIZ principles in crowd management.' *Safety Science*, 49(2) pp. 286–291.

Poeteren, F. van (2020) 'Physical Distancing in Pedestrian Dynamics®.' INCONTROL Simulation Software. 7th September. [Online] [Accessed on 6th January 2021] https://www.incontrolsim.com/physical-distancing-in-pedestrian-dynamics/.

Polus, A., Schofer, J. L. and Ushpiz, A. (1983) 'Pedestrian Flow and Level of Service.' *Journal of Transportation Engineering*, 109(1) pp. 46–56.

Predtechenskiĭ, V. M. and Milinskii, A. I. (1978) *Planning for foot traffic flow in buildings*. New Delhi : Amerind.

Public Health Agency of Sweden (2020) *FAQ about COVID-19*. [Online] [Accessed on 28th July 2020] http://www.folkhalsomyndigheten.se/the-public-health-agency-of-sweden/communicable-disease-control/covid-19/.

Public Health England (2020) *Reducing the risk of transmission of COVID-19 in the hospital setting*. GOV.UK. [Online] [Accessed on 31st July 2020] https://www.gov.uk/government/publications/wuhan-novel-coronavirus-infection-prevention-and-control/reducing-the-risk-of-transmission-of-covid-19-in-the-hospital-setting.

Pullan, P. and Murray-Webster, R. (2017) *A Short Guide to Facilitating Risk Management: Engaging People to Identify, Own and Manage Risk*. London - New-York: Routledge.

Purser, D. and Bensilum, M. (2001) 'Quantification of behaviour for engineering design standards and escape time calculations.' *Safety Science* pp. 157–182.

Quarantelli, E. L. (1954) 'The Nature and Conditions of Panic.' *American Journal of Sociology*, 60(3) pp. 267–275.

Quarantelli, E. L. (1960) ‘Images of Withdrawal Behavior in Disasters: Some Basic Misconceptions.’ *Social Problems*, 8(1) pp. 68–79.

Raineri, A. S. (2005) ‘The cause and prevention of serious crowd injuries and fatalities at outdoor music festivals.’

Raineri, A. S. (2013a) ‘A model to facilitate the development of an appropriate risk assessment methodology and instrument for crowd safety at outdoor music festivals.’ *In*. Rome, Italy, pp. 79–88.

Raineri, A. S. (2013b) ‘Contextualising risk assessment – incorporating the psychosocial dimension in assessing crowd safety risks at outdoor music festivals.’ *In*, p. 18.

Raineri, A. S. (2015) *Behavioural risk at outdoor music festivals*. PhD. University of Southern Queensland.

Raineri, A. S. (2016) ‘Contemporary Planning Approaches for Crowd Safety at Mass Gatherings.’ *In*. Melbourne, p. 23.

Rausand, M. (2011) *Risk Assessment Theory Methods and Applications*. New Jersey: John Wiley & Sons Inc.

Reicher, S. (2008) ‘The Psychology of Crowd Dynamics.’ *In* Hogg, M. A. and Tindale, R. S. (eds) *Blackwell Handbook of Social Psychology: Group Processes*. Oxford, UK: Blackwell Publishers Ltd, pp. 182–208.

Reicher, S. (2011) ‘Mass action and mundane reality: an argument for putting crowd analysis at the centre of the social sciences.’ *Contemporary Social Science*, 6(3) pp. 433–449.

Ren, L.-L., Wang, Y.-M., Wu, Z.-Q., Xiang, Z.-C., Guo, L., Xu, T., Jiang, Y.-Z., Xiong, Y., Li, Y.-J., Li, X.-W., Li, H., Fan, G.-H., Gu, X.-Y., Xiao, Y., Gao, H., Xu, J.-Y., Yang, F., Wang, X.-M., Wu, C., Chen, L., Liu, Y.-W., Liu, B., Yang, J., Wang, X.-R., Dong, J., Li, L., Huang, C.-L., Zhao, J.-P., Hu, Y., Cheng, Z.-S., Liu, L.-L., Qian, Z.-H., Qin, C., Jin, Q., Cao, B. and Wang, J.-W. (2020) ‘Identification of a novel coronavirus causing severe pneumonia in human: a descriptive study.’ *Chinese Medical Journal*, 133(9) pp. 1015–1024.

Rogsch, C., Schreckenberg, M., Tribble, E., Klingsch, W. and Kretz, T. (2010) ‘Was It Panic? An Overview About Mass-Emergencies and Their Origins All Over the World for Recent Years.’ *In* Klingsch, W. W. F., Rogsch, C., Schadschneider, A., and Schreckenberg, M. (eds) *Pedestrian and Evacuation Dynamics 2008*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 743–755.

Ronchi, E. and Lovreglio, R. (2020) ‘EXPOSED: An occupant exposure model for confined spaces to retrofit crowd models during a pandemic.’ *Safety Science*, 130, October, p. 104834.

Ronchi, E., Lovreglio, R. and Kinsey, M. J. (2020) ‘A Survey on Evacuation Model Awareness, Usage and Users.’ *SFPE Europe*, Q1 2020(17).

Ronchi, E. and Nilsson, D. (2016) ‘Basic Concepts and Modelling Methods.’ *In* Cuesta, A., Abreu, O., and Alvear, D. (eds) *Evacuation Modelling Trends*. Cham: Springer International Publishing, pp. 1–23.

Ronchi, E., Uriz, F. N., Criel, X. and Reilly, P. (2016) ‘Modelling large-scale evacuation of music festivals.’ *Case Studies in Fire Safety*, 5, May, pp. 11–19.

Rooney, J. J. and Vanden Heuvel, L. N. (2004) ‘Root Cause Analysis For Beginners.’ *Quality Progress* p. 9.

Rothan, H. A. and Byrareddy, S. N. (2020) 'The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak.' *Journal of Autoimmunity*, 109, May, p. 102433.

Rude, G. (2005) *Crowd in history*. Serif.

Safe Project (2021) *Safe Project | À revoir : Comment le secteur évenementiel peut-il résoudre les enjeux liés à la sécurité et à la crise Covid-19 ?* How can the eventy sector resolve issues related to t security and the covid-19 crisis. [Online] [Accessed on 26th March 2021] https://www.thesafeproject.eu/webinar-how-can-the-event-sector-resolve-issues-related-to-security-and-the-covid-19-crisis/.

Saldaña, J. (2013) *The coding manual for qualitative researchers*. 2nd ed, Los Angeles: SAGE.

Salute, M. della (2020) *FAQ - Covid-19, questions and answers*. [Online] [Accessed on 27th July 2020] http://www.salute.gov.it/portale/nuovocoronavirus/dettaglioFaqNuovoCoronavirus.jsp?lingua=english&id=230#6.

Sande, J. P. van de (2013) *11 manieren om naar massa's te kijken: een inleiding in de massapsychologie, bezien vanuit: individu, motivatie, systematiek, gevaar, samenleving, macht, wetten, situatie, tijd, management & media*. Utrecht: TSC Academy.

Santos-Reyes, J. and Olmos-Peña, S. (2017) 'Analysis of the "News Divine" stampede disaster.' *Safety Science*, 91, January, pp. 11–23.

Saunders, M., Lewis, P. and Thornhill, A. (2016) *Research Methods for Business Students*. 7th edition, Harlow: Pearson Education Limited.

Saunders, M. N. K., Lewis, P. and Thornhill, A. (2019) *Research methods for business students*. Eighth Edition, New York: Pearson.

Scales, P. (2013) 'An introduction to ontology and epistemology for undergraduate students.' Pete Scales.

Schadschneider, A., Chraibi, M., Seyfried, A., Tordeux, A. and Zhang, J. (2018) 'Pedestrian Dynamics: From Empirical Results to Modeling.' *In* Gibelli, L. and Bellomo, N. (eds) *Crowd Dynamics, Volume 1: Theory, Models, and Safety Problems*. Cham: Springer International Publishing (Modeling and Simulation in Science, Engineering and Technology), pp. 63–102.

Schadschneider, A., Klingsch, W., Kluepfel, H., Kretz, T., Rogsch, C. and Seyfried, A. (2012) 'Evacuation Dynamics: Empirical Results, Modeling and Applications.' *Safety Science*, 50(5) pp. 1253–1260.

Schweingruber, D. and Wohlstein, R. T. (2005) 'The Madding Crowd Goes to School: Myths about Crowds in Introductory Sociology Textbooks.' *Teaching Sociology*, 33(2) pp. 136–153.

Sciensano (2020a) 'Fact Sheet COVID-19 disease (SARS-CoV-2 virus) - Version 4.' Sciensano.

Sciensano (2020b) 'Fact Sheet COVID-19 disease (SARS-CoV-2 virus) - Version 5.' Sciensano.

Sciensano (2021) *Belgium COVID-19 Dashboard - Sciensano*. Google Data Studio. [Online] [Accessed on 25th March 2021] http://datastudio.google.com/reporting/c14a5cfc-cab7-4812-848c-0369173148ab/page/ZwmOB?feature=opengraph.

SGSA (2020) ‘Supplementary Guidance 02: Planning for Social Distancing at Sports Grounds.’ Sports Grounds Safety Authority.

Sime, J. D. (1983) ‘Affiliative behaviour during escape to building exits.’ *Journal of Environmental Psychology*, 3(1) pp. 21–41.

Sime, J. D. (1985) ‘Designing for people or ball-bearings?’ *Design Studies*, 6(3) pp. 163–168.

Sime, J. D. (1995) ‘Crowd psychology and engineering.’ *Safety Science*, 21(1) pp. 1–14.

Sime, J. D. (1999) ‘Crowd facilities, management and communications in disasters.’ *Facilities*, 17(9/10) pp. 313–324.

von Sivers, I., Templeton, A., Köster, G., Drury, J. and Philippides, A. (2014) ‘Humans do not Always Act Selfishly: Social Identity and Helping in Emergency Evacuation Simulation.’ *Transportation Research Procedia*, 2 pp. 585–593.

Smith, R. A. and Lim, L. B. (1995) ‘Experiments to investigate the level of “comfortable” loads for people against crush barriers.’ *Safety Science*, 18(4) pp. 329–335.

Society of Fire Protection Engineers (2018) *SFPE guide to human behavior in fire*. Cham: Springer International Publishing.

Soomaroo, L. and Murray, V. (2012) ‘Disasters at Mass Gatherings: Lessons from History.’ *PLoS Currents*, 4, March, p. RRN1301.

Sports Grounds Safety Authority (2015) *Alternative Uses of Sports Grounds*. London: Sports Ground Safety Authority (Sports Grounds and Stadia Guide, 5).

Sports Grounds Safety Authority (2016) *Some Thoughts On The Last Mile*. [Online] http://www.safetyatsportsgrounds.org.uk/news/some-thoughts-last-mile.

Sports Grounds Safety Authority (2018) *Guide to safety at sports grounds, Sixth Edition*. London: Sports Grounds Safety Authority.

Steinhaus, H. (1983) *Mathematical snapshots*. Oxford [Oxfordshire] ; New York: Oxford University Press.

Still, G. K. (2000) *Crowd Dynamics*. PhD. University of Warwick.

Still, G. K. (2007) ‘Review of pedestrian and evacuation simulations.’ *International Journal of Critical Infrastructures*, 3(3/4) p. 376.

Still, G. K. (2009) ‘Safety in Numbers.’ *ISquared*, pp. 23–26.

Still, G. K. (2014a) *Introduction to Crowd Science*. 1 edition, Boca Raton: CRC Press.

Still, G. K. (2014b) ‘Visualising Risk Assessment for Crowd Safety.’ *ICSS Journal*, (2 (Summer)) pp. 48–53.

Still, G. K. (2016) ‘Student -Teacher conversation on DIM-ICE.’ *Moodle Crowd Safety and Risk Analysis*.

Still, G. K. (2019) *Standing Crowd Density*. Crowd Safety and Crowd Risk Analysis. [Online] [Accessed on 10th June 2020] http://www.gkstill.com/Support/crowd-density/CrowdDensity-1.html.

Still, G. K. (2020) ‘DIM - ICE model - how to work with it.’

Still, K., Papalexi, M., Fan, Y. and Bamford, D. (2020) 'Place crowd safety, crowd science? Case studies and application.' *Journal of Place Management and Development*, ahead-of-print(ahead-of-print).

Tatrai, A. (2001) 'The Role of Risk Management in Event / Venue Safety Planning.' ASSURE Event Safety Consultants.

Taylor, P. (1990) *The Hillsborough Stadium Disaster 15 April 1989 Final Report of Inquiry*. London: Home Office.

Team Event Safety Institute en CrowdProfessionals (2020) 'Afstand houden! – hoe crowd management ons kan helpen de Coronacrisis te beheersen.' Event Safety Institute. Blog. 24th March. [Online] [Accessed on 11th April 2020] https://www.eventsafetyinstitute.nl/blogs/afstand-houden-crowd-management-en-corona/.

Templeton, A., Drury, J. and Philippides, A. (2015) 'From Mindless Masses to Small Groups: Conceptualizing Collective Behavior in Crowd Modeling.' *Review of General Psychology*, 19(3) pp. 215–229.

Templeton, A., Drury, J. and Philippides, A. (2018) 'Walking together: behavioural signatures of psychological crowds.' *Royal Society Open Science*, 5(7) p. 180172.

The Luxembourgh Governement (2020) *Call to respect social distancing in shops open to the public*. Website Coronavirus (COVID-19). [Online] [Accessed on 25th July 2020] https://gouvernement.lu/en/actualites/toutes_actualites/communiques/2020/04-avril/01-appel-social-distancing.html.

The Republic of Poland (2020) *Temporary limitations - Coronavirus: information and recommendations - Gov.pl website*. Coronavirus: information and recommendations. [Online] [Accessed on 27th July 2020] https://www.gov.pl/web/coronavirus/temporary-limitations.

Thunderhead Engineering (2020) *Social Distance Improvements in Pathfinder 2020.3 | Thunderhead Engineering*. Social Distance Improvements in Pathfinder 2020.3. [Online] [Accessed on 6th January 2021] https://www.thunderheadeng.com/2020/08/social-distance-improvements-in-pathfinder-2020-3/.

Tocher, K. D. (1960) 'An Integrated Project for the Design and Appraisal of Mechanized Decision-Making Control Systems.' *OR*, 11(1/2) p. 50.

Tong, D. and Canter, D. (1985) 'The Decision to Evacuate: a Study of the Motivations which Contribute to Evacuation in the Event of Fire.' *Fire Safety Journal*, 9 pp. 257–265.

Trudeau, R. J. (1994) *Introduction to Graph Theory*. New York.

Turner, R. H. and Killian, L. M. (1957) *Collective Behavior*. Englewood Cliffs: Prentice Hall.

Turner, R. H. and Killian, L. M. (1972) *Collective Behavior*. 2nd edition, Englewood Cliffs: Prentice Hall.

Upton, M. (2004) 'Risk Analysis for Major Concert Events The Benefit of Hindsight.' *In*, p. 9.

Van Loon, H. (1921) *The Story of Mankind*. Boni and Liverlight.

Viot, P. (2013) *Le territoire sécurisé des grandes manifestations contemporaines*. PhD. École Polytechnique Fédérale de Lausanne.

Wagner, U., Fälker, A. and Wenzel, V. (2013) 'Tödliche Zwischenfälle durch Menschengedränge bei Großveranstaltungen: (Un-)vermeidbares Phänomen.' *Der Anaesthesist*, 62(1) pp. 39–46.

Wall, A. D. (2011) 'The Kaplan and Garrick Definition of Risk and its Application to Managerial Decision Problems.'

Wang, C., Shen, L. and Weng, W. (2020) 'Experimental study on individual risk in crowds based on exerted force and human perceptions.' *Ergonomics*. Taylor & Francis, 63(7) pp. 789–803.

Wang, W., Tang, J. and Wei, F. (2020) 'Updated understanding of the outbreak of 2019 novel coronavirus (2019-nCoV) in Wuhan, China.' *Journal of Medical Virology*, 92(4) pp. 441–447.

Wei, W. E. (2020) 'Presymptomatic Transmission of SARS-CoV-2 — Singapore, January 23–March 16, 2020.' *MMWR. Morbidity and Mortality Weekly Report*, 69.

Weidmann, U. (1993) 'Transporttechnik der Fussgänger.' *Schriftreihe des IVT*, 90 p. 110.

Williams, P. M. (2001) 'Techniques for Root Cause Analysis.' *Baylor University Medical Center Proceedings*, 14(2) pp. 154–157.

Winstanley, C. (2010) *Writing a dissertation for dummies*. Chichester, West Sussex ; Hoboken, N.J: Wiley.

Wisker, G. (2008) *The postgraduate research handbook: succeed with your MA, MPhil, EdD and PhD*. 2nd ed, New York: Palgrave Macmillan (Palgrave study guides).

Wölfel, R., Corman, V. M., Guggemos, W., Seilmaier, M., Zange, S., Müller, M. A., Niemeyer, D., Jones, T. C., Vollmar, P., Rothe, C., Hoelscher, M., Bleicker, T., Brünink, S., Schneider, J., Ehmann, R., Zwirglmaier, K., Drosten, C. and Wendtner, C. (2020) 'Virological assessment of hospitalized patients with COVID-2019.' *Nature*. Nature Publishing Group, 581(7809) pp. 465–469.

World Health Organization (2015) *Public health for mass gatherings: key considerations*. Geneva: World Health Organization.

World Health Organization (2020a) *Coronavirus disease (COVID-19) advice for the public: Myth busters*. Coronavirus disease (COVID-19) advice for the public: Myth busters. [Online] [Accessed on 12th April 2020] https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/myth-busters.

World Health Organization (2020b) *Coronavirus disease (COVID-19): Mass gatherings*. Coronavirus disease (COVID-19): Mass gatherings. [Online] [Accessed on 23rd November 2020] https://www.who.int/news-room/q-a-detail/coronavirus-disease-covid-19-mass-gatherings.

World Health Organization (2020c) 'Key planning recommendations for Mass Gatherings in the context of the current COVID-19 outbreak.' World Health Organization.

World Health Organization (2020d) 'Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations.' World Health Organization.

World Health Organization (2020e) *Novel Coronavirus(2019-nCoV) Situation Report – 22*. (Coronavirus disease 2019 (COVID-19)).

World Health Organization (2020f) 'Pass the message: Five steps to kicking out coronavirus.'

World Health Organization (2020g) *Q&A on coronaviruses (COVID-19)*. World Health Organization. [Online] [Accessed on 15th July 2020] https://www.who.int/news-room/q-a-detail/q-a-coronaviruses.

World Health Organization (2020h) *Transmission of SARS-CoV-2: implications for infection prevention precautions*. World Health Organization.

World Health Organization (2020i) *WHO Director-General's opening remarks at the media briefing on COVID-19 - 25 March 2020*. [Online] [Accessed on 11th April 2020] https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---25-march-2020.

World Health Organization (2020j) *WHO recommended criteria for declaring the end of the Ebola virus disease outbreak*. World Health Organization. [Online] [Accessed on 16th July 2020] https://www.who.int/publications/m/item/who-recommended-criteria-for-declaring-the-end-of-the-ebola-virus-disease-outbreak.

Xiao, S., Li, Y., Wong, T. and Hui, D. S. C. (2017) 'Role of fomites in SARS transmission during the largest hospital outbreak in Hong Kong.' *PLOS ONE*. Public Library of Science, 12(7) p. e0181558.

Xu, T., Chen, Cong, Zhu, Z., Cui, M., Chen, Chunhua, Dai, H. and Xue, Y. (2020) 'Clinical features and dynamics of viral load in imported and non-imported patients with COVID-19.' *International journal of infectious diseases: IJID: official publication of the International Society for Infectious Diseases*, 94, May, pp. 68–71.

Young, B. E., Ong, S. W. X., Kalimuddin, S., Low, J. G., Tan, S. Y., Loh, J., Ng, O.-T., Marimuthu, K., Ang, L. W., Mak, T. M., Lau, S. K., Anderson, D. E., Chan, K. S., Tan, T. Y., Ng, T. Y., Cui, L., Said, Z., Kurupatham, L., Chen, M. I.-C., Chan, M., Vasoo, S., Wang, L.-F., Tan, B. H., Lin, R. T. P., Lee, V. J. M., Leo, Y.-S., Lye, D. C., and for the Singapore 2019 Novel Coronavirus Outbreak Research Team (2020) 'Epidemiologic Features and Clinical Course of Patients Infected With SARS-CoV-2 in Singapore.' *JAMA*, 323(15) p. 1488.

Yu, I. T.-S., Qiu, H., Tse, L. A. and Wong, T. W. (2014) 'Severe acute respiratory syndrome beyond Amoy Gardens: completing the incomplete legacy.' *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America*, 58(5) pp. 683–686.

Zarket, M., Aldana, N., Fox, C., Diehl, E. and Dimitoglou, G. (2014) 'A Study of Stadium Exit Design on Evacuation Performance.' *In*. Caine, p. 8.

Zhen, W., Mao, L. and Yuan, Z. (2008) 'Analysis of trample disaster and a case study – Mihong bridge fatality in China in 2004.' *Safety Science*, 46(8) pp. 1255–1270.

Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., Zhao, X., Huang, B., Shi, W., Lu, R., Niu, P., Zhan, F., Ma, X., Wang, D., Xu, W., Wu, G., Gao, G. F. and Tan, W. (2020) 'A Novel Coronavirus from Patients with Pneumonia in China, 2019.' *New England Journal of Medicine*, 382(8) pp. 727–733.

Zhu, Y., Chen, F. and Wang, Z. (2016) 'Research on physical force of high density crowd.' *In Procedings Pedestrian Evacuation Dynamics*.

Zoom Video Communications Inc (2021) *Video Conferencing, Web Conferencing, Webinars, Screen Sharing*. Zoom Video. [Online] [Accessed on 19th April 2021] https://zoom.us/.

7 Appendices

7.1 APPENDIX A – Student declaration 1

Student declaration - Postgraduate

Option A- Permission granted to make final year project available

I declare that this final year project, submitted in accordance with the requirements of Manchester Metropolitan University for the degree of **MSc Crowd Safety and Risk Analysis,** is all my own work and has not been submitted previously to any other institution. All source materials used in the preparation of this project, whether published or unpublished, have been duly acknowledged and referenced. All referencing is in accordance with current Institutional, Faculty and Departmental requirements.

If awarded the above degree, I give full permission for this final year project to be considered for retention for the benefit of future students and others at the discretion of the Faculty. If retained, the full content, including appendices and additional material, may be made available for retrieval, viewing, printing and/or saving by authorised users. Any such use must comply with current UK copyright legislation.

I understand that the University will only make exemplary final year projects available to others and MMU is not obliged to keep this work for any longer than is deemed academically appropriate. After this period has elapsed, I agree to the destruction of the work without further notice.

I understand that, if required, I should make a copy of the final year project for my own purposes before submission. Manchester Metropolitan University is not under any obligation to return a copy of the work to me after submission.

Signed.....

Date 19/04/2021

~~**Option B – Permission to make copy available denied**~~

~~I declare that this final year project, submitted in accordance with the requirements of Manchester Metropolitan University for the degree of **[insert degree title]**, is all my own work and has not been submitted previously to any other institution. All source materials used in the preparation of this project, whether published or unpublished, have been duly acknowledged and referenced. All referencing is in accordance with current Institutional, Faculty and Departmental requirements.~~

~~Owing to the personal/commercially sensitive nature of the content, I request that the work is not made available to others.~~

~~I understand that, if required, I should make a copy of the final year project for my own purposes before submission. Manchester Metropolitan University is not under any obligation to return a copy of the work to me after submission.~~

~~Signed.....~~

~~Date.....~~

7.2 APPENDIX B – Student declaration 2

Dissertation Declaration:

Student

No part of this work has been submitted in support of an application for any other qualification of this, or any other institution of learning. I declare that this is an original piece of work and that all data has been collected and results analysed as stated within.

This research has been conducted in an ethical manner in accordance with the University's Ethical Framework.

I have shown my supervisor evidence of data collection and analysis.

Signed..... Date...19/04/2021

Supervisor (please sign after the appropriate statement)

The student has presented sufficient evidence during supervision to verify that this dissertation is their own work and that the data collection and analysis is genuine.

Signed .....Date.....

The student has not presented sufficient evidence during supervision to verify that this dissertation is their own work and that the data collection and analysis is genuine. Therefore, I cannot verify data collection and analysis at this stage of the assessment procedure.

Signed .....Date.....

7.3 APPENDIX C – Williams' technique to determine Root Causality.

To determine the root causality, ask "Why" five times.

For example, in the case where patrons got injured or died in a fire at an event, the "fire" would be the event immediately responsible for causing the incident, making it the proximate cause. If we use Williams' technique (Williams, 2001), the answers might be:

1. There was a fire at the event. Why?
2. Not all patrons got out in time. Why?
3. The emergency exits were locked. Why?
4. The security guard responsible for unlocking the emergency did not know he had to unlock these. Why?
5. The procedure is not embedded in the guard training. Why?
6. Standard operating procedures for unlocking and checking emergency exits do not exist at the venue.

In the example, the fire can be identified as a proximate cause; the absence of standard operating procedures for unlocking emergency exits can be identified as root causality.

7.4 APPENDIX D – Overview of literature that reviews incidents.

Researcher	Publication	(Main) Event
Taylor (1990)	The Hillsborough Stadium disaster, Final report	Hillsborough, 1989
Elliott & Smith (1993)	Football stadia disasters in the United Kingdom: learning from tragedy?	Ibrox Park Stadium, 1971 Bradford City Stadium, 1985 Heysel, 1985 Hillsborough, 1989 Mexico City, 1985 Bastia, 1992
Fruin (1993)	The causes and prevention of crowd disasters	Bethnal Green Tube Station Shelter, 1943. Ibrox Park Stadium 1971, The Who, Cincinnati, 1979 Lenin Stadium, 1982 Hillsborough, 1989
Dickie (1995)	Major crowd catastrophes	Victoria Hall, Sunderland 1883 Ibrox, Glasgow 1902 & 1971 Bethnal Green, London 1943 Bolton, 1946 Hillsborough, Sheffield 1989
Sime (1995)	Crowd psychology and engineering	The Who, Cincinnati, 1979 Hillsborough, 1989
Sime (1999)	Crowd facilities, management and communications in disasters	Beverly Hills Supper Club fire, 1977 Hillsborough, 1989
Comeau and Duval (2000)	Dance hall fire Gothenburg, Sweden October 28, 1998	Dance Hall Fire Gothenburg, 1998
Still (2000)	Crowd Dynamics	20+ events
Upton (2004)	Risk Analysis for Major Concert Events, the benefit of hindsight	25+ events
Zhen et al. (2008)	Analysis of trample disaster and a case study – Mihong bridge fatality in China in 2004	Mihong bridge 2004
Earl et al. (2005)	The Management of Crowds and Other Risks at Outdoor Music Festivals: A Review of the Literature	Multiple events
Lee and Hughes (2005)	Exploring Trampling and Crushing in a Crowd	Lan Kwai Fong, 1993 Akashi Fireworks Display, 2001 Roskilde Festival, 2000 Hillsborough, 1989
Raineri (2005)	The causes and prevention of serious crowd injuries and fatalities at outdoor music festivals.	Multiple events
Lee and Hughes (2007)	Minimisation of the risk of trampling in a crowd	Lan Kwai Fong 1993
Santos-Reyes and Olmos-Peña (2017)	Analysis of the 'News Divine' stampede disaster	the 'News Divine' stampede disaster
Johanson et al. (2008)	From crowd dynamics to crowd safety: a video-based analysis	Hajj & Saudi Pilgrim related events

Researcher	Publication	(Main) Event
Harding et al. (2010)	An early warning method for crush	Hillsborough, 1989 Hajj
Challenger and Clegg (2011)	Crowd disasters: a socio-technical systems perspective	Hillsborough, 1989 King's Cross underground fire, 1987 Bradford City Stadium, 1985
Hoskins (2011)	Fire Protection and Evacuation Procedures of Stadia Venues in New Zealand	Multiple Stadium incidents
Helbing & Mukerji (2012)	Crowd disasters as systemic failures: analysis of the Love Parade disaster	Love Parade Duisburg, 2011
Soomaroo and Murray (2012)	Disasters at Mass Gatherings: Lessons from History	21 Incidents
Viot (2013)	Le territoire sécurisé des grandes manifestations contemporaines	Roskilde, 2000 Love Parade Duisburg, 2011
Wagner et al. (2013)	Tödliche Zwischenfälle durch Menschengedränge bei Großveranstaltungen	Air & Style-Snowboard-Schaukampf, 1999
Still (2014a)	Introduction to crowd science	40+ events
Pearl (2015)	Crowd Crush: How the Law Leaves American Crowds Unprotected	Multiple events
Balsari et al. (2017)	New Year's stampede, Lan Kwai Fong 1993	Lan Kwai Fong, 1993
Gayathri et al. (2017)	A review of studies on understanding crowd dynamics in the context of crowd safety in mass religious gatherings	Kumbh Mela
Still et al. (2020)	Place crowd safety, crowd science? Case studies and application	Sydney Olympics 2000 Canary Warf 2003

Table 27 – Researched crowd events/incidents

7.5 APPENDIX E – Density and Body Size

Referring to Fruin's 'Body Ellipse', Weidmann (1993) advocates that the body shape projection on the ground is an oval; Dridi (2015) opposes and suggests a rectangular projection.

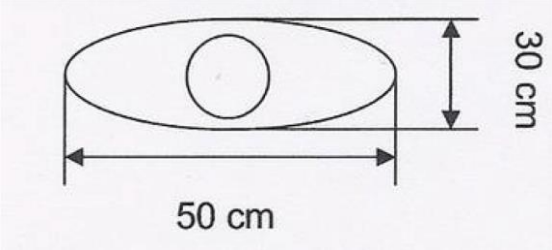


Figure 26: Space requirement and 'Body Ellipse' according to Weidman (1993)

The 'average' person has been assigned different values of space requirement. The body ellipse area of 57.9 cm by 33 cm, as set by Fruin (1987), is opposed by both Weidmann (1993) and Oberhagemann (2012), who define the space requirement of the average person as 0.15 square meter. Still (2000) advocates that Fruin's values are generous and proposes an area of 53.0 cm by 28.0 cm or an average of 50.0 cm by 30.0 cm. These values represent the 95-99 percentile anthropomorphic size margin. Motmans (2005) measured shoulder width and body depth (Fruin, 1987; Still, 2000) for the Belgian population. An average of 43.8 cm shoulder width and 23.7 cm body depth was found, and the 99th percentile was measured on 51.3 cm by 30.7 cm.

Table 2 shows the calculated body space requirements for both an elliptical projection (Fruin, 1987) and a rectangular projection (Dridi, 2015). Figures 27 to 31 give a visual representation of the body areas as suggested in a one square meter plane.

Nr.	Source	Shoulder width	Body depth	Elliptical Area (m²)	Rectangle Area (m²)
1	Fruin	0.579	0.330	0.150	0.191
2	Weidmann	0.500	0.300	0.118	0.150
3	Still* **99%**	0.530	0.280	0.117	0.148
4	Still** **Avg.**	0.500	0.300	0.118	0.150
5	Motmans**	0.438	0.237	0.082	0.104
6	Motmans*	0.513	0.307	0.124	0.157
* 95-99 percentile anthropomorphic size margin ** Average, ideal weight					

Table 28: Body Space Requirements

(1)Fruin

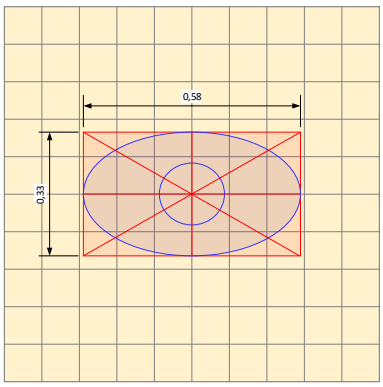


Figure 27: Fruin Body Area

(2) Weidmann

(4) Still Avg.

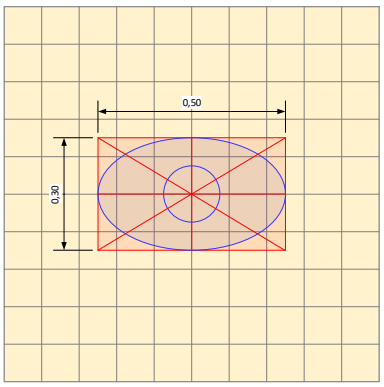


Figure 28: Weidmann & Still Avg. Body Area

(3) Still 99%

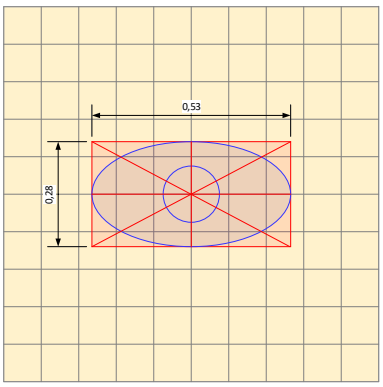


Figure 29: Still 99% Body Area

(5) Motmans Avg.

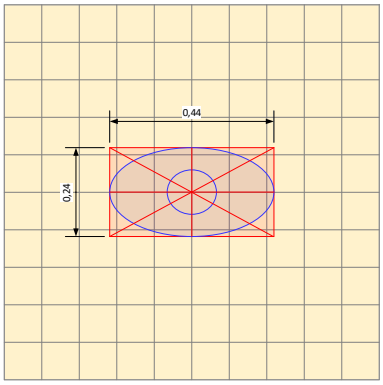


Figure 30: Motmans Avg. Body Area

(6) Motmans 99%

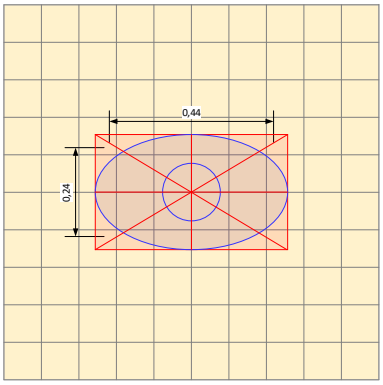


Figure 31: Motmans 99% Body Area

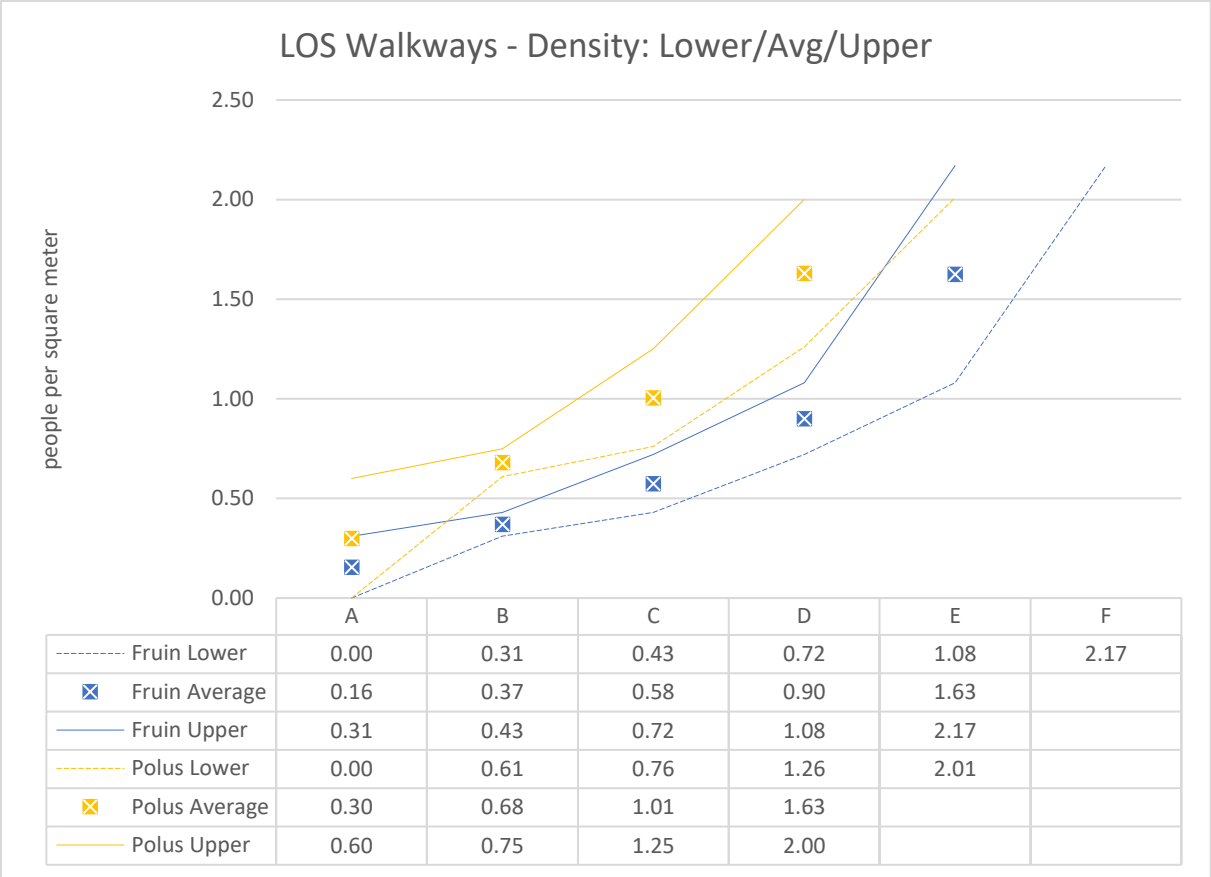
7.6 APPENDIX F – Level of Service

7.6.1 Level of Service for Walkways – Fruin and Polus

Fruin's LoS scale for Walkways goes from A, low density/flow, to F, high density/flow (Fruin, 1987). Polus (1983) uses a similar scale system but divides C into C1 and C2, and limits the scale to 5 levels, with D being the level with the highest density and flow. For comparison, Polus' C1 is considered C and C2 is considered D. The scales and levels are not comparable. Fruins values are lower per scale step than Polus'. Table 29 and 30 and Figures 32 and 33 show Fruin's density and flow values in his LoS for walkways in relation to Polus' values.

DENSITY – Level of Service for Walkways								
Fruin p/m²				Polus p/m²				Description
LoS	Low	Avg.	Upper	LoS	Low	Avg.	Upper	**Polus** (1983) / **Fruin** (1987)
A	0,00	0,16	0,31	A	0,00	0,30	0,60	Polus: Free Flow Fruin: Free Circulation
B	0,31	0,37	0,43	B	0,61	0,68	0,75	Polus: Restricted, impeded, unstable flow Fruin: Minor Conflicts
C	0,43	0,58	0,72	C1	0,76	1,01	1,25	Polus: C1 – Dense Flow Fruin: Restricted Movement
D	0,72	0,90	1,08	C2	1,26	1,63	2,00	Polus: C2 – Dense Flow Fruin: Reduced Speed, restricted reverse and crossflow.
E	1,08	1,63	2,17	D	2,01			Polus: Jammed Flow Fruin: Heavily restricted movement, flow is interrupted.
F	2,17							Fruin: Extremely restricted walking speed, unavoidable contact, loss of control, a complete breakdown of traffic flow

Table 29: LoS Walkways – Density Comparison Fruin & Polus

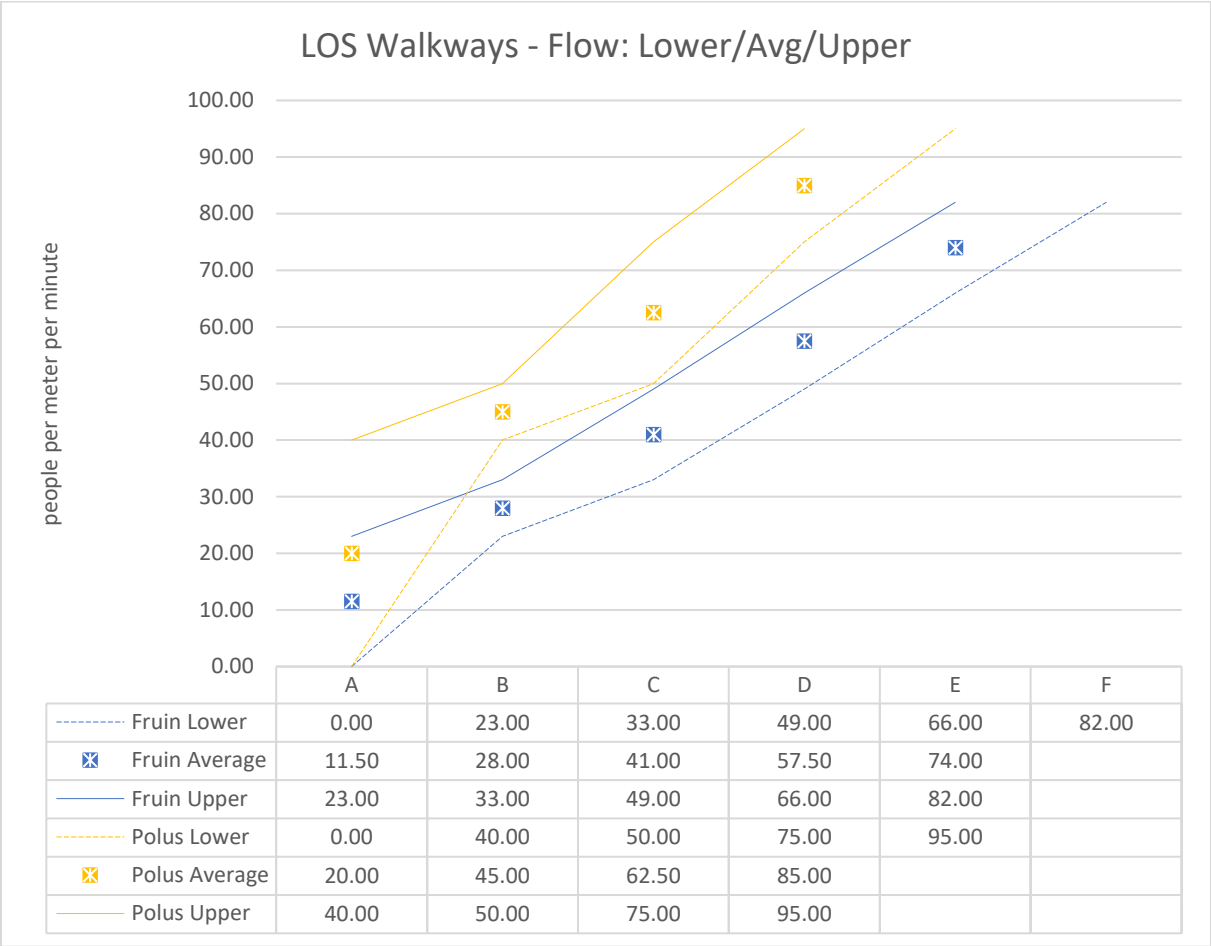


	A	B	C	D	E	F
Fruin Lower	0.00	0.31	0.43	0.72	1.08	2.17
Fruin Average	0.16	0.37	0.58	0.90	1.63	
Fruin Upper	0.31	0.43	0.72	1.08	2.17	
Polus Lower	0.00	0.61	0.76	1.26	2.01	
Polus Average	0.30	0.68	1.01	1.63		
Polus Upper	0.60	0.75	1.25	2.00		

Figure 32: LoS Walkways – Density Fruin & Polus

FLOW – Level of Service for Walkways								
Fruin p/m/m				Polus p/m/				Description
LoS	Low	Avg.	Upper	LoS	Low	Avg.	Upper	Polus (1983) / Fruin (1987)
A	0,0	11,5	23,0	A	0,0	20,0	40,0	Polus: Free Flow Fruin: Free Circulation
B	23,0	28,0	33,0	B	40,0	45,0	50,0	Polus: Restricted, impeded, unstable flow Fruin: Minor Conflicts
C	33,0	41,0	49,0	C1	50,0	62,5	75,0	Polus: C1 – Dense Flow Fruin: Restricted Movement
D	49,0	57,5	66,0	C2	75,0	85,0	95,0	Polus: C2 – Dense Flow Fruin: Reduced Speed, restricted reverse and crossflow.
E	66,0	74,0	82,0	D	95,0			Polus: Jammed Flow Fruin: Heavily restricted movement, flow is interrupted.
F	82,0							Fruin: Extremely restricted walking speed, unavoidable contact, loss of control, complete breakdown of traffic flow

Table 30: LoS Walkways – Flow Comparison Fruin & Polus



	A	B	C	D	E	F
Fruin Lower	0.00	23.00	33.00	49.00	66.00	82.00
Fruin Average	11.50	28.00	41.00	57.50	74.00	
Fruin Upper	23.00	33.00	49.00	66.00	82.00	
Polus Lower	0.00	40.00	50.00	75.00	95.00	
Polus Average	20.00	45.00	62.50	85.00		
Polus Upper	40.00	50.00	75.00	95.00		

Figure 33: LoS Walkways – Flow Fruin & Polus

Polus' values are about 45% to 70% higher than Fruin's values. The comparison above and the work of Still (2000) show that Fruin's LoS concept, although it has been a standard for engineers and architects, embeds a margin for error (Still, 2000).

7.6.2 Level of Service for Stairways - Fruin

Fruin also defined a LoS for stairways. The table and graph below show Fruin's values for stairways. The Level of Service for Stairways is more restricting than the Level of Service for Walkways; this acknowledges Pauls' (1984) concern for stair-related incidents.

DENSITY – Level of Service for Stairways				
	Fruin p/m²			Description
LoS	Low	Avg.	Upper	Fruin (1987)
A	0,00	0,27	0,54	Free Circulation
B	0,54	0,63	0,72	Minor Conflicts
C	0,72	0,90	1,08	Inability to pass others
D	1,08	1,31	1,54	Reduced Speed, restricted reverse and crossflow.
E	1,54	2,11	2,69	Heavily restricted movement, flow is interrupted,
F	2,69			Extremely restricted walking speed, unavoidable contact, loss of control, a complete breakdown of traffic flow.

Table 31: LoS Stairways – Fruin Density Values

Level of Service for Stairways				
	Fruin – Flow (p/m/m)			Description
LOS	Low	Avg.	Upper	Fruin (1987)
A	0,0	8,0	16,0	Free Circulation
B	16,0	19,5	23,0	Minor Conflicts
C	23,0	28,0	33,0	Inability to pass others
D	33,0	38,0	43,0	Reduced Speed, restricted reverse an crossflow.
E	43,0	49,5	56,0	Heavily restricted movement, flow is interrupted,
F	56,0			Extremely restricted walking speed, unavoidable contact, loss of control, a complete breakdown of traffic flow.

Table 32: LoS Stairways – Fruin Flow Values

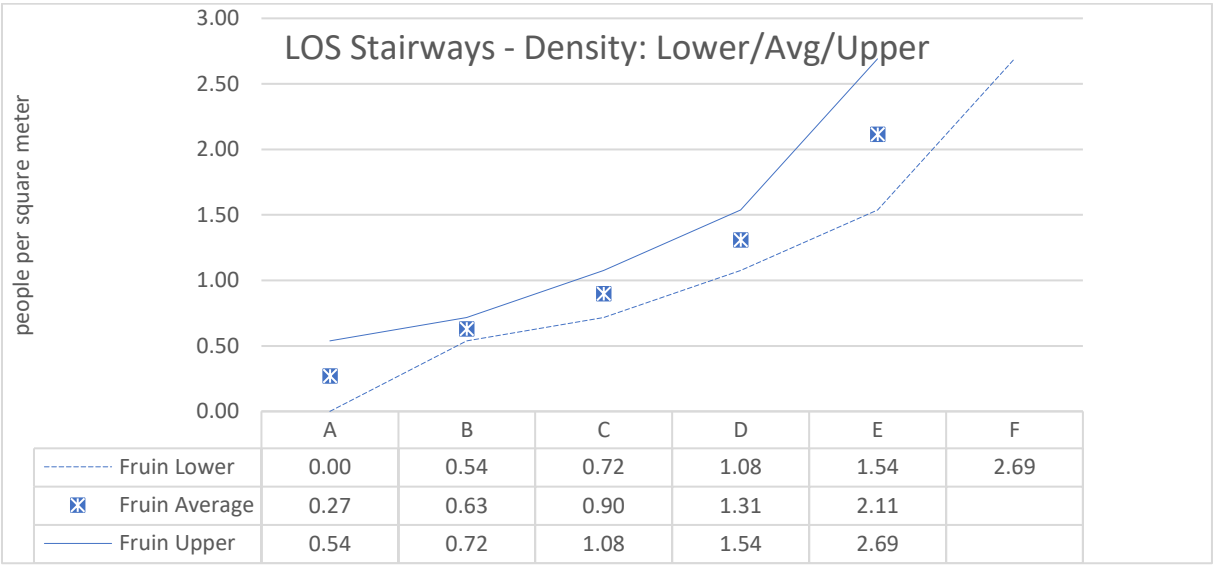
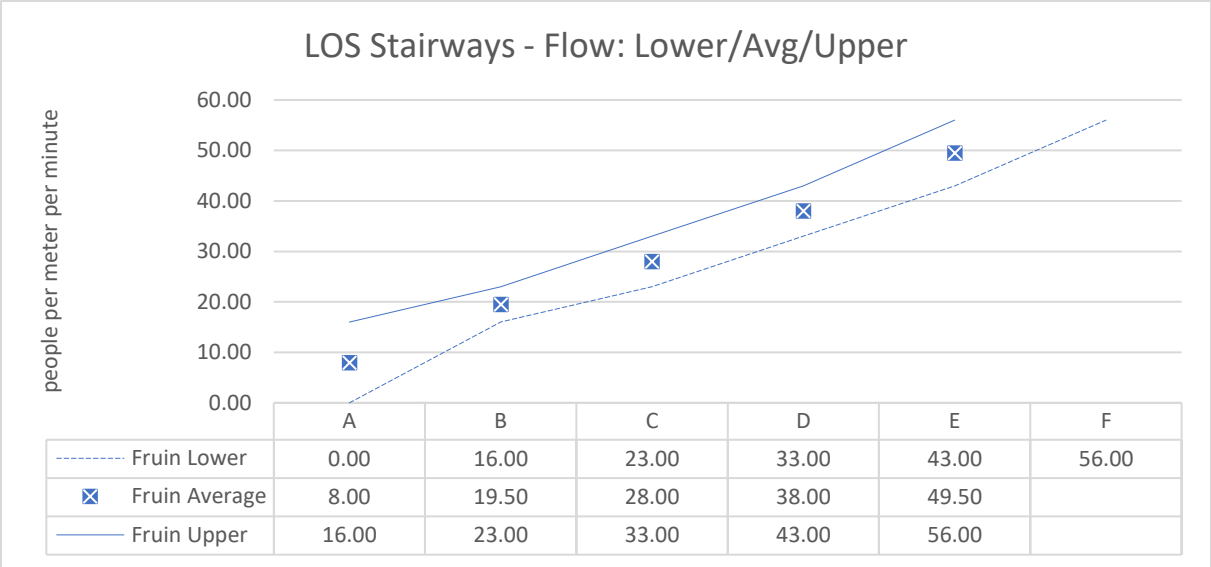


Figure 34: LOS Stairways – Fruin Density Values



	A	B	C	D	E	F
Fruin Lower	0.00	16.00	23.00	33.00	43.00	56.00
Fruin Average	8.00	19.50	28.00	38.00	49.50	
Fruin Upper	16.00	23.00	33.00	43.00	56.00	

Figure 35: LoS Stairways – Fruin Flow Values

7.6.3 Level of Service for Static Areas - Fruin

The table below shows Fruins Level of Concept for static areas in relation to the thresholds defined by Oberhagemann (2012).

Fruin: LoS Static (p/m²)				**Oberhagemann (p/m²)**	
LoS	**Low**	**Upper**	**Description**	**D**	Description
A	0,00	0,83	Free circulation zone, without disturbing others.		
B	0,83	1,08	Restricted circulation, without disturbing others.		
C	1,08	1,54	Circulation disturbs others, disturbance of personal comfort zone.		
D	1,54	3,59	No-touch zone, standing without personal contact. Circulation is restricted.	2	No risk, a possible trip slip or fall does not affect other people.
E	3,59	5,38	Touch zone, personal contact is unavoidable. Circulation is not possible.	5	Movement is possible but limited. Applied forces can be absorbed.
F	5,38		The body ellipse. Close contact with others.	6	Movement is still possible. Applied forces cannot be absorbed as lunging is impossible. A force of about 500-600 N can be created, and crowd surges can occur. Enough to cause flail chest (Kroll et al., 2017).
				8	Densities higher than 6 p/m² are believed to be involuntary and enforced. Nearly the maximal value of 8.2 p/m² for the Central European Average Person.

Table 33: Fruins Level of Service and Oberhagemanns thresholds

7.7 APPENDIX G – Physical distancing values in Europe

Country	Distance (m)	Reference
Belgium	1.50	(FOD Binnenlandse Zaken, 2020a)
Bulgaria	1.50	(Bulgarian Government, 2020)
Cyprus	2.00	(Cypriotic Minister of Health, 2020)
Denmark	1.00 – 2.00	(Danish Health Authority, 2020)
Estonia	2.00	(Estonian Government, 2020)
Finland	1.00	(Finnish Institute for health and welfare, 2020)
France	1.00	(Ministère du travail de France, 2020)s
Germany	1.50	(Federal Ministry of the Interior, Building and Community, 2020)
Greece	2.00	(National Public Health Organization, 2020)
Hungary	1.50	(About Hungary, 2020)
Ireland	2.00	(Citizensinformation.ie, 2020)
Italy	1.00	(Salute, 2020)
Croatia	1.50	(Croatian Institute of public health, 2020)
Latvia	1.00	(Latvijas Republikas Veselības ministrija, 2020)
Lithuania	2.00	(Lithuanian Government, 2020)
Luxembourg	2.00	(The Luxembourgh Governement, 2020)
Malta	2.00	(Government of Malta, 2020)
Netherlands	1.50	(Ministerie van Algemene Zaken, 2020)
Austria	1.00	(Federal Ministry Republic of Austria, 2020)
Poland	2.00	(The Republic of Poland, 2020)
Portugal	2.00	(Ministry of Health Portugal, 2020)
Romania	1.50	(Grupul de Comunicare Strategică de Romania, 2020)
Slovenia	1.50	(Government Communication Office, 2020)
Slowakia	2.00	(Ministry of Investments, Regional Development and Informatization of the Slovak Republic, 2020)
Spain	1.50	(Ministerio de Sanidad, 2020)
Check Republic	2.00	(Government of the Czech Republic, 2020)
Sweden	1.00 (arms length)	(Public Health Agency of Sweden, 2020)
United States	1.83 (6 feet)	(CDC, 2020)

Table 34: Physical Distance rules in Europe (April 2020)

7.8 APPENDIX H – Crowd Management Tools vs Virus Transmission

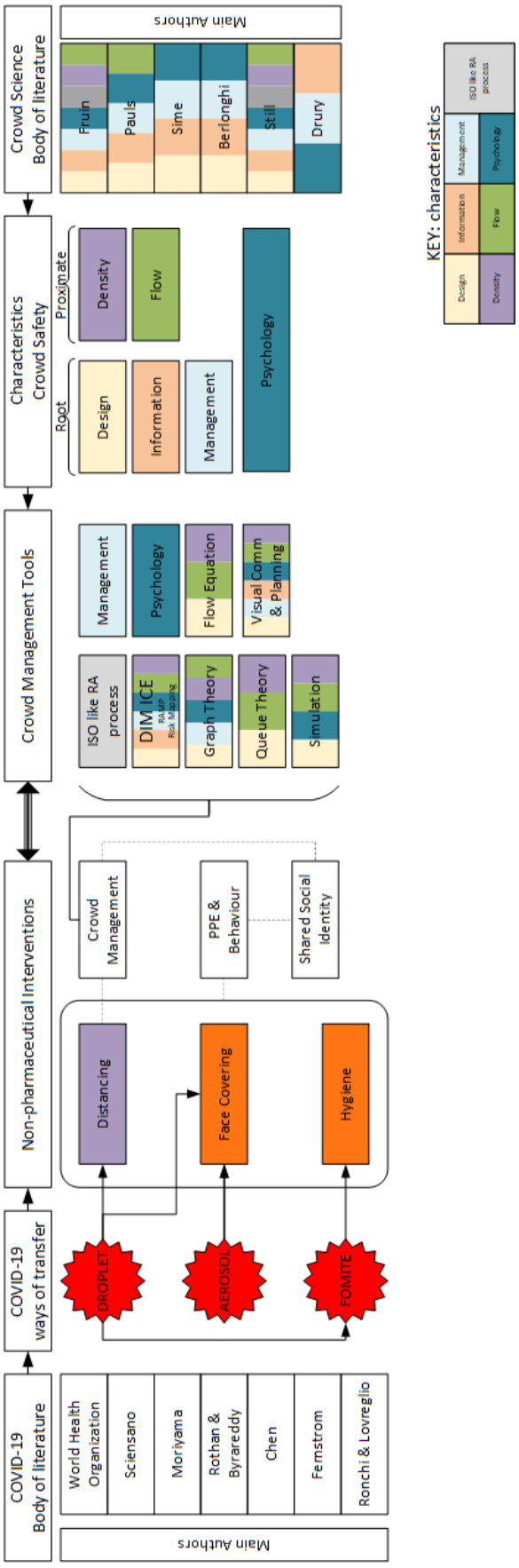


Figure 36: Crowd Management Tools vs Virus Transmission (enlarged)

7.9 APPENDIX I – Interview questions and their rationale

Nr.	Questions	
1	Q	First of all, thank you for your participation and welcome to this interview. This interview consists of open-ended questions. Please feel free to answer freely and talk about your knowledge and experience on the subject. The goal is to gain insight into the characteristics of crowd safety and the crowd management tools used to implement non-pharmaceutical interventions to prevent the transfer of respiratory viruses such as COVID-19. Do you permit me to be interviewed for my research and video record this interview for transcription purposes?
	R	Give a short recap of the purpose of the interview and gain confirmation for the interview and the use of video recording.
2	Q	Can you tell me something about your professional background, studies, level of experience and current job title?
	R	Check Sampling criterion 1
3	Q	Did you have any training on crowd safety or crowd management? What was it about?
	R	Follow up question for question 2.
4	Q	Can you tell me something about your experience with events, mass gatherings, or places of public assembly during the COVID-19 pandemic?
	R	Check Sampling criterion 2
5	Q	Did you take any training or courses to inform yourself on COVID-19 and the prevention of virus transmission? If so, what was the content of the course?
	R	Follow up question for Question 3.
6	Q	Let us first talk about your experience in crowd management in general. What is your definition of crowd management? Or what definition do you stand by?
	R	Gain insight into the respondents' views on crowd management.
7	Q	What type of Risk Analysis methods did you use when managing crowds at events, mass gatherings or places of public assembly, pre covid?
	R	Gain insight into the commonly used methods for Risk Analysis in a crowd management context.
8	Q	In your experience and knowledge, what are the main characteristics of crowd safety?
	R	Gain insight into the respondents' views on crowd safety.
9	Q	When we consider that crowd management tools can be (1) a theoretical framework, (2) a method, a way of doing things, procedures, an equation…, or (3) technical and software solutions. What crowd management tools did you use to manage crowds pré-covid? Can you give an example?
	R	To gain insight into the rationale behind the use of crowd management tools.

Nr.	Questions	
10	Q	Are there any crowd management tools you know but did not use pré-covid.
	R	To gain insight into the rationale behind the use of crowd management tools
11	Q	What are the reasons for not using these tools?
	R	To gain insight into the rationale behind the use of crowd management tools
12	Q	Earlier, we talked about the Risk Analysis methods used before COVID-19. Did COVID-19 change the way you conduct Risk Analysis for? Do you still use the same tools?
	R	Gain insight in the respondents used for Risk Analysis methods and the rationale behind this use.
13	Q	What is your expert vision on (1) Mass Panic?
	R	Gain insight into the respondents' views on human behaviour in emergency situations.
14	Q	Are you familiar with the theory on (2) Shared Social Identity? If so, in the context of events, mass gatherings, or places of public assembly, do you implement this and how?
	R	Gain insight into the respondents' views on the use of crowd psychology for crowd safety.
15	Q	What is your vision on the relation between Distancing, Density and capacity?
	R	Gain insight into how the respondent links the concept of distancing with density.
16	Q	How do you go by distancing? Way of measuring? Static? Dynamic? And why?
	R	Gain insight into the respondents' views on the technicalities of distancing.
17	Q	Has COVID-19 changed how you express or talk about the number of people and their relationship with the available space? Do you express this as p/m², or has this shifted to area/person or another way of expressing it?
	R	Gain insight into how distancing changed the view on density?
18	Q	When we consider that crowd management tools can be (1) a theoretical framework, (2) a method, a way of doing things, procedures, an equation…, or (3) technical and software solutions. What crowd management tools do you use to manage crowds and to implement the non-pharmaceutical intervention of distancing at events, mass gatherings or places of public assembly? Can you give an example?
	R	To gain insight into the rationale of the use of crowd management tools during COVID-19
19	Q	Are there any crowd management tools you know but do not use? Why do you not use these tools?
	R	To gain insight into the rationale of the use of crowd management tools during COVID-19

Nr.	Questions	
20	Q	In your expert opinion, what kind of 'non-existing crowd management tool would be useful to manage crowds in times of COVID-19 or 'normal' times?
	R	Gain insight into the needs of those managing crowds at events, mass gatherings or places of public assembly.
Q = Question / R = Rationale		

Table 35: Interview questions and their rationale

7.10 APPENDIX J – Consent Form

30/03/2021
Bert Bruyninckx
MSc Crowd Safety & Risk Analysis
School of Operations, Technology, Events
and Hospitality Management
Building
Manchester Metropolitan University
Tel:

Manchester Metropolitan University

Consent Form

Title of Project:

Events, mass gatherings, and places of public assembly, can traditional views and tools for crowd management assist in the implementation of non-pharmaceutical interventions to prevent the transfer of respiratory viruses such as COVID-19?

Name of Researcher:

Bert Bruyninckx

Participant Identification Code for this project:

	Please initial box
1. I confirm that I have read and understood the information sheet dated 29/03/2021 for the above project and have had the opportunity to ask questions about the interview procedure.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason to the named researcher.	☐
3. I understand that my responses will be sound and video recorded and used for analysis for this research project.	☐
4. I give/do not give permission for my interview recording to be archived as part of this research project, making it available to future researchers.	☐
5. I understand that my responses will remain anonymous.	☐
6. I agree to take part in the above research project.	☐
7. I understand that at my request a transcript of my interview can be made available to me.	☐

Name of Participant	Date	Signature
Researcher	Date	Signature

To be signed and dated in presence of the participant

Once this has been signed, you will receive a copy of your signed and dated consent form and information sheet by post.

7.11 APPENDIX K – Participant Information Sheet

Participant Information Sheet – V2.0 29/03/2020

Study Title

Events, mass gatherings, and places of public assembly, can traditional views and tools for crowd management assist in the implementation of non-pharmaceutical interventions to prevent the transfer of respiratory viruses such as COVID-19?

Invitation

I would like to invite you to take part in a research study. Before you decide you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or if you would like more information. Take time to decide whether or not to take part.

For myself, I have been working in the event industry since 1998. First within a security company where I was responsible for operations, now, as a licensed security and safety consultant for both corporate and event clients. Currently I'm working on my Master Thesis to fulfil the requirements of the MSc in "Crowd Safety and Risk Analysis" with the Manchester Metropolitan University. To meet the research objectives, I have chosen to conduct expert interviews.

What is the purpose of the study?

Since the COVID-19 outbreak early 2020 the concept of physical distancing as a non-pharmaceutical intervention has been used around the world to prevent the transmission of COVID-19. This study explores to what extend traditional crowd management views and tools can be used to facilitate physical distancing and the prevention of transmission of respiratory viruses.

This, in order to draw conclusions and make recommendations to those managing events, places of mass gathering or public assembly on the future strategy for coping with respiratory virus outbreaks.

Why have I been invited?

As a security, safety, or event professional, you have been chosen to take part in the study because of your knowledge and experience in this field. In total, 6 to 8 international experts will be interviewed.

Do I have to take part?

It is up to you to decide, participation is entirely voluntary, and you are free to withdraw at any time, without giving a reason.

If you decide to take part in the study, you will be informed on the study and the next steps.

We will then ask you to sign a consent form to show you agreed to take part.

How will the interviews be conducted?

The interviews will take place online with the use of MS Teams. The interviews are recorded for transcription and future reference.

What will happen to me if I take part?

If you decide to take part in the study, we will decide on when and how the interview is conducted. A date and time will be agreed upon.

The interview will take 30 to 40 minutes and will be video and audio recorded. The recordings will be transcribed for analysis.

Anonymity and Confidentiality

All information given from participants will be treated as confidential and not identifiable unless agreed otherwise. If you decide to take part in the study, your data, the interview record and the transcript will be held securely.

All results used in the Master Thesis will be anonymised.

Expenses and payments?

As this is a student research project, no expenses or payments can be made for participation.

What will I have to do?

If you agree to participate, you will receive a pre-interview letter with information regarding the research process and the parts of the interview.

To guarantee reliable results, we kindly expect you to provide full and honest answers.

What are the possible disadvantages and risks of taking part?

The interview will take about 40 minutes and there are no risks involved in the interview.

What are the possible benefits of taking part?

We cannot promise the study will help you but the information we get from the study will help to increase the understanding of how crowd management can be embedded in strategies for coping with events and places of public assembly in the case of respiratory virus outbreaks.

What if there is a problem?

If you have concerns about certain aspects of the study, you can speak to the researcher who will try to answer your questions. The contacts details of the researcher can be found at the end of this information sheet.

If you are not happy with the way the research is being conducted or wish to talk to the research supervisor regarding any other serious matter, then please contact: Mr. Shaun Litler (Principal Lecturer at The Manchester Metropolitan University) s.litler@mmu.ac.uk

Will my taking part in the study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential, and any information about you which leaves the university will have your name and address removed so that you cannot be recognised.

The data will be collected via semi-structured interviews. These interviews will be recorded and then transcribed. The data will be stored safely.

Participants research interviews will be anonymous and given a research code, known only to the researcher.

A master list identifying participants to the research codes data will be held on a password-protected Sharepoint accessed only by the researcher.

Hard paper/taped data will be stored in a locked cabinet, within a locked office, accessed only by the researcher.

Electronic data will be stored on a password protected Sharepoint known only by the researcher. The recorded data will only be used for this study.

Only the researcher and the supervisor will have access to identifiable data.

Data will be held for a minimum period of 3 years and then will be disposed of securely.

What will happen if I don't carry on with the study?

If you withdraw from the study all the information and data collected from you, to date, will be destroyed and your name removed from all the study files.

What will happen to the results of the research study?

Results of this study will be an integral part of this thesis that will be submitted to Manchester Metropolitan University, in partial fulfilment of a Master Study.

Further information and contact details:

If you have any general enquiries regarding this study, then please contact:

Bert Bruyninckx

+32 492 93 42 58

Bert.bruyninckx@stu.mmu.ac.uk

7.12 APPENDIX L – Interview Respondent #06

Researcher: Well, that should appear on your screen as well. So, you are notified that I am recording this.

R#06: Not Yet. Oh, now, now, it's, it's now. I can see it, yes. All right. I want I'm...

Researcher: Yes, and I am gonna share my screen with you because I have written out my questions as well, because English isn't my first language, so it might be easier for you sometimes to read what I am saying. So, but anyway, the working title of my research is Events, Mass Gatherings and Places of Public Assembly. Can traditional views and tools for crowd management assist in implementing non pharmaceutical interventions to prevent the transfer of respiratory viruses such as covid-19. So basically, what I'm trying to figure out is that the crowd management tools we traditionally use or used can they be used in covid-19 times or similar occasions. So, it's all about crowd management and the tools we use to, to manage our crowds. So, first of all, thank you for your participation and welcome to this interview. This interview consists of open-ended questions, so please feel free to answer freely and talk about your knowledge and experience on the subject. The goal is to gain insight into the characteristics of crowd safety and the crowd management tools used to implement to to implement non pharmaceutical interventions to prevent the transfer of respiratory viruses such as covid-19. Do you permit me to be interviewed for my research and video record this interview for transcription purposes?

R#06: Yes, I do.

Researcher: OK, so first of all, can you tell me something about your professional background studies, level of experience and your current job title?

R#06: I am a I'm a crowd safety manager. I studied crowd safety management at the Bucks University from 2010 on I would say. I'm working in the event industry as a production manager and… As a production manager since some 30 four/five years now and for the last 20 years, I'm working as a safety manager as well. I was for many years, I was working for a venue management company, doing all safety management things and crowd management aspects, and I quit there in two thousand eighteen. Since 2010 I'm, I'm a stakeholder in a small company, a training company called Ibit in Germany. We would say we're, we're a small company. We're still market leaders in questions on crowd safety aspects around while around events just one side. But on the other hand, as on, well, crowded places, you know, like that's, that's what it's about, including train stations and plain... and stuff and so on. So that's my that's my background. I'm there's, I have a qualification, which is called Maister fur farnshaf und safety. It's kind of a master of event technology, which is a German, which is a German qualification that you have to have if you work and if you work in legal venues, then you have to provide this qualification. And I'm also a health and safety officer. That's why I'm so

everything I do since my, since the beginning of time felt and since the beginning of my profession is around, it's around safety of people. I'm still learning more and more. So therefore, I'm therefore, I'm also interested in such, in such research projects because I like the ideas of people and sharing these ideas. And it's always, I always get something out of it just for, you know, like for free, just an hour we spent. And you get something. I get something that's brilliant. So that's, that's what it is. My current job title is a senior consultant for Crowd Safety Management.

Researcher: OK, thank you. Um, I guess the next one we already touched. Did you have any training on crowd safety or crowd management and what was it about.

R#06: Yeah, well yeah. I'm beside my, beside the studies. I am, I'm a member of the Strategy Board of the European Safety Group, the YES-group. And we are organizing and of course visiting one to two annual meetings, seminars, workshops, seminars. And again, so it's all, all about crowd management. And I learn a lot from these from these events as well. I think that we met in MAMA that was, that was, that that was in that environment as well, providing some seminars and just have exchange with professional.

Researcher: OK, can you tell me something about your experience with events, mass gatherings or places of public assembly during the covid-19 pandemic?

R#06: Yes, well, we, we, we write hygiene and infection protection concepts for gatherings. Well, not, maybe not mass gatherings, as we are not allowed to do any of them, but even for, for kind of TV productions that we do so with you, where you have some, some 60, 70, 80, up to 100 staff people on stage and a thing so that we, we work around that. And I did some, some smaller events where, where people from press and industry and politics came together for, I don't know the English expression, but it's just like a hundred fifty people at the same time, at the same place on the covid-19 rules. And we and we are teaching. That's what we do mainly since last year with teaching. We teach in hygiene and infection protection courses full. Meanwhile, I would say a few hundred people that we that we, that we get that go through the seminars within sharing all their experience on their events as well. So therefore, it's just it's a steep learning curve.

Researcher: OK, so did you take any training courses yourself to inform you on the covid-19 and the prevention of virus transmission? And what was the content of those courses?

R#06: Yes, we, I've been through that. I've been through all our own programs as well. And it's about it's, it's a, it's, it's, it's two topics. One is, one is the topic to write concepts for safe events on the covid routes. That's one thing. And the other content is to be, to be the, the officer of the Hygiene and Infection Protection Officer on site. So, what's it and that's two different things. One is the theory in advance, and one is the operations and the operations on site. And I've been through both of these programs. On one hand, the concept program means

it's you know, it's a protection concept, you know, whether it's, it's an evacuation plan. If it's if it's if it's a big concept for the safety of the whole event. Now, it's about now this one is about infection protection. They all follow the same. They all follow the same rules right there. There's some kind of protection goal that is that that that that we will that we will reach that we're trying to reach. And then there is the then there is that the, the threat analysis. Right. It's just like to see what powers are against our protection goals. So, this is what it is. And then there is then there is the kind of an assessment that means with all these which is working against us, which has that high priority, which has a lower priority. And then we go to measurements and say, right, what can we do to, to deal with it, to, you know, to deal with the risk that that that is there. And how do we next step, how do we get it into our organization? So, operations on the side and then, well, it's a management circle, right. Then it shows like then be there, look at it. Did it work? Didn't it work? What went wrong? So, start, start the circle again. So that's more or less the content about it. So, it was a, it was a risk management. It's a risk management circle with the with an emphasis on infection, you know, like following, following the visitor through all processes that we that we install. Right. If it's queueing before your registration, if it's if it's if it's the if it's the tracing and, you know, like checking IDs and whatever we have to do, every single process has to be investigated under the under the infection idea. So that's, that's what we're what we're talking about in the concept to fight it. It's a kind of a special risk analysis and risk assessment action. And then we've been through that, and then I've been through the other program, which is that that officer on site and this is more on, you know, like hands on actions, right. You know, like, how do I have 60 people? They want to have some drinks from a refrigerator. How do we get how, which process do we install to make sure that they don't just like, like infect themselves by just touching the fridge and stuff? Do we, do we provide gloves or do we, do it with some paper handkerchiefs? What do we do? So, every single step, how do we check them in? How do we make sure that that we know who is there, who is not there? How do we make sure when they leave and all? And it's again, it's the same it's the same idea, just like on the practical ground. It's just like following that that stuff through all the way, like, you know, like them, they, they are not allowed to smoke inside. So, we have an area outside, which is the smoking area. So, there is some kind of an exchange from the outside to the inside, people just like meeting themselves. How do we protect them from, from other passing by people? So, this is every single thing, just like on, hands on, this is how we do it. And plus, that's an important thing, of course, the briefing on it shows, again, just like we have to find the right solutions for that situation, and we have to make sure that people know about it, because most of the time that it's not they want to do it wrong. They just don't know. And then again, it's, it's, again, my duty to make sure that they know to be there. And of course, then it's just like being all around. And I used, we use a for other events. We use a crowd management program, the Safe Side program. It's an app on the, on a computer which is usually used to, to exchange documents, to have a lock from of the of your event and stuff and

bring in all the emergency documents in there so everybody can just have it on this on this mobile and has it available and with, with the safe side guys together, we, we try to translate the whole thing into that covid operations thing. And that's what I did. So, I wrote again, I wrote a lock on the whole thing. I documented all my, you know, my inspection around. So, I documented mistakes people did. And I documented how I how I face these, these, these mistakes and what I did to improve my briefings on that stuff like that, if that's what, what, what we what we what we did in that. So that's, that's what we what we try to that that's what we try to learn on the in our teach, in the program. And I've been through that as well. And I and I put it into operations a few times already.

Researcher: OK, so now, before we go to the covid-19 issues, let's first talk about crowd science, crowd science and your experience in general. What is your definition of crowd management or what definition do you stand by? What is what is crowd management for you?

R#06: Well, I'm I used to… I used to stick to the to the Fruin definition, which is the crowd management, the I don't keep it. I don't have it all in mind. Right. It's a, it's the, it's the, it's a systematic planning for and the, the continuous supervising and leading and directing, directing of the assembly and the movement of people so that something like that crowd management is to be, is and is. Well, it brings together both concepts, the planning phase and the operations phase. And it's got to be, it's got to be, it's a, it's a holistic… It's got to be a holistic view. You can't only just write and concept, but not be on site to look whether the concept works or not and what shall work is that we, that we have and that we have an eye on the crowd and have some kind of values that we can, that we compare what we see against our planning. And see, this is what I, what I expected, what I expected. It's good, right? So, let it go. So, for. Oh, maybe there's. If, if not that, then I have to somehow softly just deal with it right now, not just put it, put a barrier in front of it. Stop it, stop it, stop it. It's just like, you know, like it's a, it's a… It's a permanent process in information directing, empowering people to do it right. So, it's just like confirming very good. You're here, you're on the right way. Just go ahead. Nice to see you. Right. It's, it's including, it's including my whole organization around you to make them, to make, to make them understand the spirit. And the spirit means that people are more or less self-competent. But we have to, we have to provide an environment where they can, where they can work, that they can understand. And we have to understand. We have to understand and with situations and in which what our environment is not self-explaining. And if so, then we have to deal with it again. Right. Plus, we have to, have this the normal mode. Right. So, plus we have to have the whole emergency mode thing. I mean. Yeah, so the whole DIM ICE… The whole DIM ICE idea is something that I carry as a, as a thinking model and carry it with me and use it for nearly every situation. So that's something about it.

Researcher: So, is there for you a difference between crowd management and crowd control?

R#06: Oh, absolutely, yes. Crowd control is… Crowd control is a part of a crowd management aspect. But it's a, it's that… It's that reaction on, right. So, my I'm aiming to not use any crowd control measures by just. And have an eye on everybody at all times to make sure that, that the flow is smooth and everything's like our, like the audience expects us, right. So, it's just like it's us saying this is the attraction. Come to us, right. And the audience comes. That's what they do, right. They come over because that's the attraction. And we have to deal with the profile, with the, with the typical behaviour. We have to bring that into our environment and make sure that they can take that that they can live out as much as they want from the typical behaviour, because that's you know, it's not our audience job to think about how they can survive the whole day. It's our job to think of that. And the audience just, you know, like they yeah, they can just, just have their party as they want to. So, yes, it is, it is, it is a difference. But the crowd control means. But I still have to have tools that make sure that we can use the crowd control aspect so we can bring in material. We have stuff on hold to maybe block to redirect and we have all that equipment that we need to talk to the people, you know. Like not that 15-year-old megaphone, which just doesn't reach far more than five meters. And, you know, just like make sure that we can react on something. And, and the more we bring into the crowd management aspect, the better the people feel, the more we communicate during the whole time, right. To, to prove, you know, in on the normal aspects that we are, that we are, that we are a source of. What's that called. And to think of for. I have to just translate for seconds. Back in a minute. I'm looking for a word which I, which will not come to my mind is reliable. So, we have to prove in the normal conditions on the normal world, we have to prove that we are a reliable source of information. And if we do so all the time, just like the constant, a constant presence to show them: 'we are here, we are here to help you', and that can help us with any crowd control measure. If they, if they met us a few times as us as our organisation, that means every, every single staff member, every security or stewards at any door, you know, if they meet him, if they ask him some something or her and they have the right answer, all they can say, I don't know that. But if you look over there, there's my supervisor. He or she can help you. If they have a, if they have the experience or audience experience is a positive experience, then we can easily put in crowd control measures. All right, everybody, you have to stop for a while. I'm sorry for that inconvenience, but we have an issue over there we have to solve. We keep you informed and then, you know, then you take it, you carry the measures along with the crowd, keep them informed and stuff. And then you, you know, like and then you relief the whole thing with an information. If we are a reliable source of information on the normal mode, then we can use crowd control measures as well. If we just jump in with it, just from nowhere, then acceptance will be low. And, and the question will be how long that crowd control measure will last until people just get angry and of trying to find different ways, you know, around the barricades, over the barricades or whatever we whatever we try to stop them from doing.

Researcher: So, what type of risk analysis methods did you use when managing crowd events, mass gatherings of places of public assembly pre-covid?

R#06: Well, it's a mixture of, of, It's a mixture of things. First of all, my first model is that customers journey model. So, I follow, I follow my customer through… Well, at least at least the operate, operate, operations areas like starting maybe at the state, at the train stations, at the parking areas, and then follow them over the walkways and whatever ways they have to use to get through the ingress situation. Get, you know, due to the whole circulation thing, whatever event is on, maybe it's just a seated the event somewhere. Maybe it's a… I don't know, maybe it's a racing event. Maybe it's a sporting or whatever it is, we have to follow them. And then through the egress phase, the departure phase again to send them back. So that's the first thing. And then we do, I do my, I do my work for the single phases. It's like arrival, egress, ingress and egress and departure. I do a kind of a technical definition. So, what do I want to…? What do we want to achieve in this certain area? You know, like on the parking area, my protection goal will be to come up with protecting people from getting hurt by cars. So, from that point on, I will find some measures that I can install just to make sure they have enough signs to see what's around to, to do some kind of traffic guidance in that environment. And that's what we do for a single phase, do single protection goals and then go through that, through that circle… the management circle. So, as I explained earlier, I use, I use common models like the DIM ICE model. Of course, it's always DIM ICE is always a starting point for me from an evaluation standard. So, once I started with that customer journey, my virtual, my virtual model, I just go to the parking area and look at it and have that DIM ICE idea as an evaluation aspect, so from design aspects. What do I find? Do I find clear… Do I find a clear separation from their strengths and cost or is it just, is it just wild everywhere? And what do I find? What would I need to, to get a preferred, preferred environment, preferred situation? So that's, that's what we do. So DIM ICE is something that I follow. And with that and maybe well, pre-covid, it maybe with covid more than before. I used the RAMP model like routes, areas, movement a profile because this is something in… If we talk about covid protection it's very particular on site, right. It's not just the general approach. We all know the general approach, but the problem is, is with all the details so that we're just deep in. And, and therefore that RAMP model is, from my opinion, one, which is… will work well. Which routes do they take right on? But exactly right now I'm planning, I'm planning a kind of a marketing stall. That's, that a recycling a big local recycling company is doing because they want to, they want to improve the use of sustainable, sustainable cups and stuff. So, that's what they, that's what they want. And from there, I just like, you know, like we do the same thing. It's the customer's journey. But I follow my, I follow the, the, the visitor from the first step on very detailed. How do they, you know like, how do we do the tracing. Is there any kind of an app, do they use pencils? How do we, how do we go with dependent's routes like following the routes. And then there are areas where they can just somehow, somehow interact with, with that stall that you

then, that is, that is put in place. So, what's that interaction about? How do they touch, what do they touch and stuff? So therefore, it's very, very interesting. Then movement... So, do they just walk through it just like a one way? Do they have to go forwards and backwards? So how do we deal with that if that, if that movement is interesting and what's the profile of, of the audience? So, to whom do we speak? What do we, what can we expect from them, you know? Like it's, this is something where you might expect maybe a more intellectual audience, because they are their mindset is about doing something well for the environment. If this, is it, then it's something else…? Then if you would talk about an environment for football fans on the way to the stadium on the Saturday afternoon. So therefore, again, it's about acceptance. It's about, it's about an idea of do people follow the rules. So therefore, RAMP is something that I used before covid. But much more with covid now.

Researcher: OK. In your experience and knowledge, what are the main characteristics or elements of crowd safety?

R#06: The main characteristics, will you help me with that question, I'm not sure whether I really understand well.

Researcher: When, when we, when we talk about crowd safety, what are the main topics or main elements that we should talk about when we're talking about crowd safety?

R#06: OK, well, that's quite a bunch, of course, but… well, space is for sure something that I always start with. And what I think what is not clearly understood by lots of people who are not into crowd management at all, but they do. But they're into safety. Well, that's, that's one of the problems I have. We have in Germany. And I know from the YES-group that we have the same problems all over Europe. There are people in charge for safety, well, either on the private sector as well as on the, on the authorities side that have to deal with the safety of the audience. But they don't understand the, the, the crowd management concept as they don't know, then that's it. It's lots of, it's lots of fire protection, of course. And it's about static's, you know, like you build it up and it's going to stand out and not fall down or something like that. That's something that's that, that lots of engineers are deeply in and lots of regulations are made under this, under this, under this aspect. But crowd management, simple crowd management things are not understood. So therefore, I would say space and the use of space is something that is a, is a, is a vital element. That means it's not just measuring two hundred square metres. And then it's just like, all right, there's two people per square metre, so it's good for 400 people. Full stop. Well, that's the approach that we know in Germany very much. It's like that's, the, they know one figure and they use it for everything, right. So that's, that's what I know. But the important aspect is to see: 'all right, there is a space, and this space has a kind of a function'. So, it's, it, it is, it is there to suit people for maybe A. standing in front of a stage dancing around or do any mosh pit activities. B, it's a, it's a space where we just want people to… should just pass through so that it's only movements, right. And then there are spaces where we mix them

up, what we want to move them through. But on the left and the right, we, we offer beer and we, we offer food, and we offer merchandise and whatever. So therefore, we have to, to define the capacity of these areas means, we have to define the function and make sure that we, that we find a kind of level of service, a level of quality, maybe more, to make sure this is the level of quality for that certain function. If it's just standing and dancing, nobody cares if it's three people per square metre. But if it's like, if I want people just to walk through because it's a transit area or maybe a… an area to, to try to bring people from, from, from, from one stage to the other to the camping, to the back to the parking, you know, like if it's, if it's an area where people have to cross in multi directions. Then, we have to think of very different uses or usage of space. So that's what I think. It's one of the most important things of crowd management to understand the differences in space that we use and to find the right, the right figures and the right levels of quality to make sure that people have a good experience in any single area that they use. If I have to if I have to break it down on just a very small aspects on crowd management, I would say that this is one of the most important aspects, for my experience, that show that people don't know. And I really see lots of, lots of safety concepts where this aspect is not, not explained. And you cannot, if it's not and if it's not understood. And if it's, if it's not understood, then it's not prepared and people will not have any resources for dealing with that, they will not do the calculations on it if they don't do the calculations on it, they will not have any supervising staff. So, there's a chain going on just because they did the mistake in the very beginning and will have a long chain of things going, that might go wrong. Let's say that it's always a potential right, but it's that's, the that's the potential.

Researcher: OK, thank you. When we consider that crowd management tools can be a theoretical framework or a method, a way of doing things, procedures or an equation or technical and software solutions, what crowd management tools do you use to manage crowds pre-covid? Can you give an example?

R#06: Well, yeah, OK.

Researcher: OK, sorry.

R#06: Well, after to read the question again, circumstantial tools to ... Well, it's, it's not so easy to say because it's of course, it's not just like one tool, it's just like always, as I already said, it's quite a combination of. But let's say let's, let's, let's have a look at, let's have a look at one very successful event that we, that we were working and we were working on, on, on the Church Youth Day in Germany. We had a, it's not, it was not too big. There was some like, like thirty-five, forty thousand attendees. And they, they have the main, while there were two main areas of events, one was the all-day event and so on the fair-trade area they lived, so they slept in the halls over there and in other halls they were all that program that, that church used. They have like smaller stages with some music, working groups, you know, like it's all about that. Everything was on that site. And next to that was the arena that I was, that I was working for

as well. And this time it's about, it's, it's a sixty-five thousand capacity arena. So, no problem to put forty thousand people in, but we had to move them from the fair-trade area into the arena and back, and the event was over four days, and in the four days, there were five occasions where we brought them in and out and in and out, right. So that was, there was an evening event on the first day. There were two, two events in the arena, one on the Friday morning, one on Friday evening. So, they had to go in there and out there. And 10 years before we had a, we had, we had the same event going on. And I was just working on the, in the, on the arena. This year I was working for the whole thing. And when I was doing, when the first time it was, there was, people understood that there is a short way from the arena to the trade fair area. So, everybody just like moved the same way, right. So, you can I can imagine how it was. Of course, it was the shortest way. And they had to walk through one big gate, which was our arena gate. No problem to get the people on there. But then they had to, then they filled up to that street that was just like in front of it. Then they filled up the station, which was in front of it, and then they had to go up, they had to go up some stairs to get into the fair trade again. And, you know, it was no, there was no critical situations, but there were ugly pictures. That's what I concerned. It was people all over the place, very nice people, you know, like a Christian youth, let's say that nice, polite, no pressure, very easily addressable. Hey, everybody, stay calm. Stay back a little bit. And then they did. There was no problem. But it was something that when we started this time, we said, all right, these pictures, we don't want to see them this time anymore. So, we have to deal with that. And that was well, that was one thing that we said from all theoretical framework that was coming from, customers journey, risk analysis and all the things we came to, to the, to the conclusions that we have to, that we will split the whole attendees into four groups, and we will provide them with four different ways to the arena. So that was what we planned for. And, and we implemented it from the very first moment on. So, with their, with their, with their invitation, they already got information when they and when they filled out the attendance form, they got the confirmation back and it was just like: 'hey, this is your business, your business, your confirmation, you're in Welcome, you're on the red route'. So that was, everybody was cleared, you know, then they got you know, and then we followed that, we followed that color code through, through everything. So, they got red wristbands. They got, they had the red on the passes and stuff to make sure that our staff on the operations can see from everybody can just, you know, like, like show the wristbands and say: 'I'm, I'm red, I'm on the right route'. All Oh, look at this, this is red. You're on the green road. Come out of here. We just bring it in position. So, we followed the whole idea on, on dividing these groups, bring them on the right way and stuff. And, and then we did all that, all the whole, the whole DIM ICE aspect. So, we measured the width of the waist and the length of the waist. Well, we were, they were corresponding with all ingress and ingress gates. We calculated on flow rates. We, we supervised the whole thing. We, we had two, one in the arena for the arena and one overall multiagency control rooms that I am, that I implemented into the whole thing because I

want everybody available. I want to see all the pictures and I want to like that's, that's how I understand this, my job on that side. And then we, you know, like then we did the whole thing on information lead in with, you know, huge really. Well, I must say that, that that the church management, they did everything, everything that we, that we came up with, they were brilliant clients. I will say, you know, they put up everyone. They put huge, huge signs, color code, the number, the number on. So, it's, it's, it's red. It's route one. Everything on that. Everybody had to understand wherever they were on the, on the on the fair-trade site, you could look around and you knew exactly if you're on the red route and you want to go to the arena tonight, then this is the way I have to go. So, it was like then we had we had cameras on the, on the, on the tracks so we could always see how it works. We had stewards and there were volunteers and professional stewards working in teams. So, they were all on the way just to report back. You know, it was it was, It was that, yeah, it was that being present all the time for every question, for every single little thing that happened, they could call us back and said, we have we, have an accident here and we have I have an issue here. I don't understand. It looks it looks different than I would, I would assume it should look, then we could go there and have had a look at it. We were we were there any time. I think this is maybe, maybe, maybe this is this is the tool that I'm talking about. It's just like: 'be there'. You have to be there all around the place. When we move people, we have to be there and, and see if they move as we expect them to move, if they move as we planned for, right. So, do they use it as it is. And, and one of the, one of the stories was the green route was a long road. So, most of the other three routes were about 500, 600 meters. But the green I had to split them up because I had to, I wanted to avoid that, that is, thirty thousand people just move around your arena in a very, in a very tight surrounding. So therefore, I sent one group far out. So, they had to move for about, let's say, one point two kilometers. So, it was more it's not, it's not too far away. Some of us, you know, we were lucky with the weather and, but the church management was concerned. They said, listen, it's this is so far and people will complain about it and can we do it like this and this and this. And I'm a friend of routines, right. So, if this is, this is another, this is another tool that I use. It's just like I want people to learn how it works with the routine. So, they are this again, this is the idea of a self-competent people, right? They can they know they understand the environment and they, they use the environment as I want it want them to use. But they can't. If we, if we do it one day this way, then they start this and this. If we if we change all the time, then they cannot learn it. So therefore, I wanted them to learn the way to make sure that we have. There was a long list of advantages that the green route has and there was. But there was an option, an idea of a shortcut on halfway. But it would have, it would have let the whole bunch of people to the ingress gates from the site, right? So, on the, on the same level, it was just like he had the gates and they came in here. So, we would have had an accumulation on the, on this side somewhere or we had to remove them to up and then down again. It was so, so much. And then we, then there was one meeting. I explained my concerns and we agreed

on the green route as I planned. Then everything was fine. Then there was the next meeting and we went through all the issues and then somebody and I could bet for that somebody came back and said, oh, listen, can we talk about the green route again? It was just like, OK, we can talk about it again. So, then we discussing it again. I was down my concerns, I said, yeah, alright, so we stick to the green route. Yes, we stick to the green route until the next meeting. Then we did something else and then the green route came back on the, on, on the track again and then I just once decided to come up with the DIM ICE evaluation analysis again. Again, one of the best tools I ever worked with in my thride. It's a pen. It's a piece of paper and all right. You want to know what I think? This is what I think. And I wrote it all down just like the long green, green route and the shortcut green route. And I put a color code on beneath it. So, there was no red because the was not life threatening. You could manage that. But there were a few, there were lots of yellow things, yellow marked aspect, and there were quite a lot, still quite a lot of orange marked aspects of it. And, in comparison and this is it, that's, that's what that tool is so brilliant and easy about, in comparent to the, to the green room. Where, where, where the long road is just like green, like it's just like, look at this, you know, it's your decision again, you know, like but my opinion is the same opinion, like the last 15 times we discussed it. And it will be the same the opinion for the next 50 times we'll discuss it. So therefore, using, using the DIM ICE evaluation as a, as a communication tool as well, is this is a simple thing. Did I answer your questions to that? Answer your question. I'm not sure whether I really got it right.

Researcher: Well, it's yeah. You, you mentioned the tools you use to... if there are any other tools, you can just name them if you want to, without giving examples or you can give examples if you want to. You, you mentioned DIM ICE and signage and RAMP analysis as tools and calculations.

R#06: Yeah, that that well, it's well, the other thing is levels of service, all levels of quality, something that we use like, customers journey, DIM ICE, RAMP, while Fruin's FIST is always in the back. But it's, you know, like it's it's like I'm a friend of positive concepts and so therefore using it. Yeah. But I think a risk, risk analysis or risk management circle, of course, is something that we use and then we get into, if we get into emergency management and it's not it's not really crowd management any more tools used. And it's just like emergency management tools, like scenario-based actions, multiagency control rooms is something that we, that we have to use. What I'm, I'm really fighting for and. Yeah. And the resilient organization. So, you know, working on scenarios but have scenarios on hand from the one side and a resilient organization, including a permanent multiagency control room where we all sit together is something that we would to take on both, in both modes. So, on the normal aspects and on the emergency aspects as well, right? All right. Yeah.

Researcher: Are there any crowd management tools you know about but don't us? In pre-covid or ...

R#06: No, I think well, maybe there are crowd management tools, I don't know, so I didn't use them, but I think everything that I, that I learned from, from Keith and Chris and whatever guys, clever guys all around, I tried to use from, for my own, for my own comfort as well. I mean, it's about, it's about documentation. It's about, it's about communication with people. So, if we have working tools and models that we can share with each other, with each other, we are, we are all much further in, in the exchange of knowledge than just by saying but by, you know, like just like providing numbers and said, this is it. So therefore, I'm, I'm, I'm real friends of sharing knowledge and sharing tools. So, you know, a little more.

Researcher: What is your, your idea of using simulation for, for managing crowds or for making concepts,

R#06: If you know what you if you're an expert and you know what you're looking for, I'm a friend of simulations. If simulations are sold to people who have no idea for lots of money, who don't understand, who don't have the right questions, it's just like, is it safe? You know, like then you can simulate everything that you want, and you could always come up with the asset safe or no, it's not safe. So, I think simulations are very good tools as long as everybody who's involved in a, in a decision, in a decision around these, around the simulations knows what simulations are and what the real question is. So, what do we have to look? What exactly is it we want to know? And if you, if you're if you're not into crowd management, you will never be able to define the question that shall be answered with your simulation. And on the other hand, we have so many, so many companies offering simulations which are computer experts and simulation experts, but have no clue on crowd management at all. And if it's, if it's, if, if, if all goes wrong, then you have my mother asking somebody with a simulation. My mother has no idea on crowd management, right. So, and she's asking, she's she wants something and discuss that with a computer expert who's got no idea as well. And then they find something out, which I don't know, but it cost you twenty thousand euros and somebody else just looks at it and say, oh, that's a simulation done. And it's, it's got a positive report. The whole event is safe. So, it's, you know, like you need experts to understand the whole process. The question beforehand, you need experts on the, on the simulation side so they understand crowd management and crowd behaviour. And you only have to have people to ask the right questions to understand the results and then find the right solutions with the results. So, this is what it needs. If you have that. I'm fine with simulations. If you don't have them, they, they provide a false safety, right. So that's if so, then they provide false safety. And I think this is, this is even more dangerous than if you just like, if you just work with your, with your low-tech tools and maybe, maybe know where you are, not sure. And then, you know, OK, I have to go there and have somebody there who's reporting me back all the time because I don't know

about the situation if they're stimulated or wrong because of the wrong questions. Somebody said this area is fine and I have nobody there to look at, right. So therefore.

Researcher: OK, that's a, that's, that's clear. Earlier we talked about risk analysis methods before covid-19. Did covid-19 change the way you conduct risk analysis, and do you still use the same tools?

R#06: Well, in general, I use the same tools. But because, you know, we don't have to do the risk analysis on covid anymore. You know, it's not just like it's done all by the government. As I said, you know, if you look at the circle, it's just like they already, they already defined the protection tools to the protection goals. We don't, we have to look at our health system. Our health system has not to break down. So, the analysis says if people meet and if the infection rate is high, our system will break down. So, the analysis is done as well, so they said that people have to, to stay away from each other. Then the assessment is done. As they said, it's high. It's a pandemic. It's just like everybody's going to die, right. So, they did the assessment as well. And they also offered us all the measures. They said, all right, here we go. You have to keep distance. You have to wear a mask. You have to clean up or disinfect areas. You have not to meet up with people. You have to do this here is, you know, like you have we have, I don't know, 10 measures that we have to do. The only thing that we still have to do if we come up with an event or a production or whatever is, is to explain how we implement it, you know, like in detail, how do we do it? How often do we, do we disinfect the pencils that the people use to write, to write their names for the tracking down and how do we open the refrigerator, right? And how do we deal with, with, with dirty dishes and stuff? So, we know it's all done in that, in that, in that question by others. And we just have to. We just have to. And again, I used to say, I think I take that customer journey idea. I follow the customer through the whole system that we provide and look for the infection possibilities where they, what do they, what they do. and they meet, where is an area of a, of a certain service where, where the flow maybe, maybe interrupted. So, people if the flow is interrupted, so there's a higher amount of people coming in, then coming out, then there will be, then there will be a kind of an assembly of people. So, and so then if I know that this is the area where that happens, I have to provide enough space to make sure it is it's you know, it's from my point of view, I use exactly the same tools. It's just another, it's just another question that is, that I have to answer with all the tools. Well, in the end, you know, like in pre-covid, we were looking for high densities in front of stages on ingress areas. And we were talking about what is a high density of tree and four people, is it five people over a short time. What we, we were discussing that. Now we discuss and it's high density if we have two people on six square meters. But it's the same. You're right. If I reach, if I reach a point of this is a, in this environment, this is the critical density, then I have to step in and do something, right. I have to come up with a kind of a crowd control measure, which means I'll hold on, please. You can't go there. It's already crowded. What? It does not look crowded. Yes,

that's right. It does not look crowded, but it is crowded. So, go for it. Live with it, right. We do exactly the same. It's just like we have to, we have other, other, other criteria to, to interfere, right. You know, earlier without covid we wouldn't. But with covid, we do know that's, that's, that's what it is. We have lower capacity, and we have lower flow rates and all that stuff. Yes, that's it. We have to live with that. But the tools that we use and the measures we take is exactly the same.

Researcher: OK, I see. So now, for something slightly different, what is your vision on, on mass panic?

R#06: There is no mass panic. There is no concept of mass panic as we, as we learn from all the clever guys, what we see, what we can see is or what is often called a mass, mass panic. It is a very rational reaction on the threat. And then, people will just try to bring themselves into a place of safety. And it always, it only goes wrong if we have not enough space, if we don't have enough exit stuff, if there is no information. And, you know, like if we don't, if we're not around to, to keep up with the crew, with the crowd, to guide them, to give them the important information than it will, then it will happen, that accidents happen. But it's not about mass panic. It's, you know, like if you look at it and, you know, I mean, you, of course, know John Drury as well as I do. And if you look at him and all these colleagues researching in that area, I must say it's always, mass panic is, is a, is a and a word which is wrongly used for, for mis organisation of space, for example. That's what I that's, that's, what I what I think it is. And if you're and if you look at and if you look at, for example, the Love Parade, which is really a well-documented tragedy. He had the things you see on the ramp, at the stairs, and at that trussing, is people helping each other, right? It's not just like pulling people down the stairs and then, and then tried himself to get up. It's just like help them up. Helping the next up, helping the next up. It's like there's so much cooperation in this, in this situation in a life-threatening situation. It's a situation in which people died. They did at the same time as people around were helping other people to get away from that situation without just like fleeing on their own. No, they'll call it of course, they will call it mass panic, but I can't see it. And I understand the concepts of the crowd psychologists who try to understand, who tried to explain. There is no concept of mass panic.

Researcher: OK, so I'm sure you're familiar with the theory on shared social identity. Is that something that you knowingly implement in your concepts or in your planning or how do you go about that?

R#06: Well, of course I know the concept. I'm not, I think I, I think I carry it with me in, in my backhead somehow, so maybe it's just like, It's just like, I'm sorry, I'm just like, if I look at my window, it's just the world is just going down and it's just like it's a horrible snowstorm outside. OK, coming back to the social identity, I think I used the concept more when I'm working in an environment where I would not expect a kind of social identity, where I have more the mass

and not, and not the, the crowd, you know, like that, that, that common crowd. We all share that one thing that keeps us together. If this is, if this is an event or a football event or a concert then, then I would more or less think, all right, they will have some kind of common feeling. I use the knowledge about the concept. If we come up with on, on stations, airports, maybe shopping malls and stuff like that, if we work in this environment, I much more keep this concept in mind. Think of, of, a maybe higher frequency supervision on an, on the different, on the different communication because of sharing communication in the crowd is easier then sharing communication in well, in a mass or in the crowd that is not that is not connected to each other. So therefore, I would, I would think on, on the communication level, I would think different in that environment.

Researcher: OK, thank you. So, what is your vision on the relation between physical distancing density and capacity?

R#06: Well, what's my vision on that? I think it's, it's a kind of, it's a kind of mathematical equation, right, it's something like that. If I have a, if I have a, if I have a given distance that I have to keep, then I have to, then I have to see what the density, what the density can be and in maximum, so that would mean if I have see, seated area, I know that I don't know that I'm losing 50, 60 or 70 percent of the seats so I can arrange people around it and. What I think is important for capacity is not just the question on physical distance and density in that I mean, in the event area, but I think that more or less like the number of toilets, number of bars and stuff available will have, still, already have a much higher influence on the calculation, on capacity than we have. You know, like if, if I, if I go into, it into an arena with 5000 seats capacity, I can easily bring in, I don't know, 500 people, right. But if I have, if I have not enough if I only have one toilet area, you know, like what people have to queue because I cannot use all the toilets at the same time, then maybe the queue and space in front of the toilet is and, in the end, give him the capacity of the whole thing and not the seating in there, right. It's just like I could easily do maybe thousands. And I just in the end I end up with three hundred people because of the toilets and the usage of it. And that, is that what you what you're aiming for in that question?

Researcher: Yes, yes, thank you. If we go to the more technical side of physical distancing, there are mainly two ways of measuring distance out there, one way is to measure the distance between one center of one person to the other and the other way is measuring between shoulders or whatever between, between bodies. What is your position on that?

R#06: I think this is, this is in my in my conceptual world, it's easy to answer because we are following a protection goal, right. That was what it was. And they say the aerosols can, can get up to one meter 50 on, over the air. So, if I want to make sure that my aerosols will not match you, then we have to, then we have to have one meter fifty between faces and bodies. So that's, that's what I think. It's not the center of somebody, because then we have some, I don't

know, 20, 15, 20 centimeters here. And then there is that there is, then is that space that we are that we're losing. And I think then we, if we look at it, then we will come, then we'll come down to something like a meter, which is which is only a meter between our faces, for example. And if so, I would think we're not matching the goals, on that's... you know, like.

Researcher: Look, that's, that's clear. Thank you. In the context of physical distancing, how do you feel about differentiation between static and more dynamic areas?

R#06: Yeah, that's, that's, that's, that's the problem. We're talking about functionalities in areas beforehand. And I think it's, it's much easier to, to put them statically into certain into a certain pattern with all that distance between. But if they start moving from A to B, because even if they.... even if they used the if you use a one-way concept, for example, if the crowd is moving, then we have to, have to, have other. Well, other assessment tools to say this is this is a this is a safe movement or it's not safe. Right. So therefore, I think that we have to, well, we will, we will see that we, that, that that's doing the events on the covid rules will be much more supervised in the in the areas where we usually don't look to, too much to write. It will be it will be that corner. It will be that areas where people will meet, where people assemble from different, from different areas where people come from the from the upper stands and from, from the infield and meet in the in the stair, stairway. This is these will be the areas where we have to where we have to look at and will have much more, will have much more staff working on there, just like, you know, like arranging and organizing the movement of people to make sure that we have this this, this bunch of people is moving this way. And these people up there have to stop for a while and then we have to mix them to make sure that we don't bring that we don't bring crowds together because then we will not keep distance anymore. And they will face each other at a certain, in a certain angle, will not work in the same direction, stuff like that. That will be, that will be the big challenge, I think. Mm hmm.

Researcher: In the context of physical distancing and events, mass gatherings and places of public assembly, what's your vision on the individual or cluster approach? What I mean is that we started out with physical distancing last year in March, and there had to be, there has to be a certain distance between each individual. Last year, in the summer, at least in Belgium, some events were allowed that you could go to with a cluster of people, the people you live with or some friends you could go to an event with six or 10 people at a certain time. How do we calculate capacity at that moment? Do we assign the same area as before to each person, or do we calculate some sort of group or cluster area? How do you feel about that?

R#06: Well, I've seen I've seen this concept as well. We tried to do some events in summer last year, and one was just an individual approach and the other was the cluster approach where two or three, four, up to 10 people were was a lot. I think it was the same as in Belgium in the summer where I could see that. And of course, it had it had an interesting effect on the capacity that you could see. It was one event was just like whether it was the same venue, it

was the same seating. And the individual approach came up to something like nine hundred and sixty people. And the cluster approach was something like seventeen hundred. Right. This is I mean, you know, we all know we make we earn money with the last five hundred tickets, not with the first thousand five hundred. And so therefore that was, that was interesting to see. I think the cluster approach is a. It is an easy explanation to higher capacities without having control on it, you know, like you cannot, you will not be able to, to control the whole thing all day, all from the same household and all they you know, like how do they did, you know, then maybe just, they might just be colleagues and not even working in the same room. But they know that it wants to see the event and they just phone and just pretend to be. So, I think. From, from the event side, from the need to, to come back to normal somehow, cluster approach, if it would be legal, it could be an idea. From the from the risk management view, I would say it's, it's not really, it's not really operational. It's like we can just pretend it's safe, but we cannot, we cannot be sure.

Researcher: That's and that's mainly because we, we, we don't know who belongs to the cluster or not.

R#06: You know, like it's just like, you know, it's just like relocating the problem. Right. So, if I if they can be together in there we have somewhere outside have to have an area where we have to keep them and distance and find out and think of, you know, if even if it's just a thousand people where 500 of them say that they somehow belong together, how do you check that out? How does it take you? So, it's getting it's that process and people waiting. We have to bring them through that process them and bring them in. And then we don't know any more. So, then they can easily mix up two of the ten, just sit down there and two others, which we haven't seen before. Just step in and say nice to meet you here. But yeah, come in. We just lost two guys and we what, we can be ten, you know, like it's just like it's not controllable. It's an idea to, to bring our business back. Yes. But it's not it's not the measure to, to keep the infection down.

Researcher: So, no. has covid-19 changed, how you express or talk about the number of people and their relationship with the available space, do you express this as people per square meter or have they shifted to area per person or another way of expressing.

R#06: Well, in the end, in the end, it comes back to people per square meter, but of course, it's in my thinking, it's, it's all, end up and up to... the people per square meter is something that is in Germany is very common. That's the that's the expression usually is used. And the other way it's the area per person is something that I have in... that I have much more in mind. Now it's just like it's more a picture, right? It's that it's that single person in in a certain area. And then there's another it's like a bubble, right? It's like just like this. And I think this picture is much more or much, more something that I have in mind now today when I think about it.

Researcher: And if you have that area per person in mind and depending on the distancing value, in Belgium it's one meter and a half, I think in Germany it's one meter and a half as well. If you picture that that area per person, is that like a circle with a radius of point seventy-five or is that a square or how do you go by that?

R#06: Yeah, well, it's, it's, it's, it's more as, as we talked about it, I would measure shoulder to shoulder 150, which then comes, comes to a quite high number because it results in something like four point four point two square metres per person. And I wouldn't do it. And yes, it could be a circle. But, you know, like with the space in between, it just doesn't work. So therefore, it's, it's, ends up in squares and, and they are quite, quite big. So therefore, you have some, some two and a half persons per ten square metres, something like that. Right.

Researcher: Yeah. OK. So, this is basically the same question as we had before on the tools you used before covid. Did the tools change now to manage physical distancing?

R#06: Well, it does not. Not, not in my planning, but, of course, in the operations. You know, like if I if I have if I if I if I calculate an area in front of my ingress turnstiles or whatever, and I would say like it's just like, you know, three people per square meter during the process. No problem for me. I have five hundred square meters. Maybe somebody who comes in and say, like, like if it's getting crowded you can say, well there are a thousand people on or something. Today would be just like more, much more with the individual right. I would be just like being there and just like and have a personal approach. Right. It's just like talking to people say, listen, you have to keep distance. Sorry, sorry for interrupting, but please keep in mind, would you be so kind and have your mask right on your face. So, it's, it's a much more intense it's a much more intense relation and, and communication level. Yeah. It's this will change. And I to be honest, for the small events, it's possible. I have no idea how that could look, how that could look in a bigger event, because the need to put people in place to make sure that they can talk to the people and make sure that they keep distance means that we have, again, have to reduce capacity because otherwise they just they just can't keep the distance. It's very, very difficult. I think that it will be. It will be it will be the need to and it will be much more need to, to individualise communication with the people, you know.

Researcher: OK, we already talked about this one. It's about a specific crowd and covid-19, oriented methods of risk assessment. I think we, we covered that.

R#06: I think, too. I don't I didn't change it. I used I used the whole process that is provided by the government.

Researcher: So, you when you... you already mentioned that you take the customer journey into account where people can go, but what with all the facilities are within, within the venue. Do you use any tools or methods to analyze those routes or people flow?

R#06: Well, I think that that RAMP is for sure. That's the tool that I use. Just see, I mean, it's not a... most of the time with the low capacities that we're talking about, it's not a problem. It's usually not a question of all the routes and areas capable of. But also, but, but only to say what's, what's, the where is the minimum capacity is which, which area, which route and provides the, the least space. Because this might, might just, just determine that the maximum capacity that I have to work with. So, that's what we, what we use. But RAMP is a perfect, is a perfect tool to use therefore, for my opinion.

Researcher: OK, do you use any tools to embed human behaviour, your crowd management plans?

R#06: Oh, I mean, of course, behaviour is something that I put in, and I don't know if you've seen the American ANSI standards on crowd management, which was... which came up, I think, in October last year, something. I think Eric Kant was working on that as well. And I was talking to Eric and, he was, he said that they put in the DIM in the DIM section of design information management. They added to the expectations. And what I really liked on it was that two-way perspective. So not only what do we expect from the audience, but also the idea of what does the audience expect from us in the certain in that certain faces during the event. And that's something that I just picked up, not just because of Covid, but something that I would say that that I have in mind, though, because I really like the idea on, the, on that two-way perspective and from that side, I would I would say that human behaviour slash human expectations is something that I, that I take into, into my crowd management plan. Yes.

Researcher: OK, thank you. So, do you use any software application or ICT tool to study or manage crowd flow? Or to implement physical distancing?

R#06: We tried a few, we have some corporations with some with some companies, but in fact it's they're quite they're quite new, these corporations. And in fact, we had no events since more than a year now. No, there's nothing to too much done in that. But I would use them as one, as just one tool, just knowing that software has its limits and camera perspectives have its limits. It's you know, it's just like one tool in the toolbox. And I think that we use them. What if we use them? We have to, we have to play in the whole concept of, of using tools from the from the personal observation to calculations to movement to, to the look at moving patterns back to camera pictures and whatever we have as much as we have. If we if we understand what were the limits of the single tools, then I think I'm a friend of doing that.

Researcher: OK, so. If you could describe or order some sort of new crowd management tool and you can go totally wild, what kind of tool would you like to have?

R#06: I would like to, I would like to have more influence on the on the phases, on arrival, departure something. Because, you know, like it's there's that there's that needle eye somehow, you're right. We, we tried to, to deal with, with values that we cannot influence

because, you know, like there's a train, there's a train load coming and then there's a train load coming. And we have to deal with it at the moment that they, that they, that they approach our area. And I would really love to have more, more control on that on that time from the parking area to the, to the, and the train station, you know, like bringing people in with more information, you know, like it's well, it's that last mile idea to, you know, like to drive more to to have more control on the last mile. That's something if that if there could be something somebody coming up with a brilliant idea or brilliant tool, I would, I would buy it.

Researcher: And is that to gain me more insight into the arrival rate or the…

R#06: More, more, more information on that, on that, you know, like we once did a show with One Direction, I was show in 2014 and all the kids from all over everywhere, the forty-five thousand came to our arena and I was just like, all right, that's the challenge. Right. And, and it was so easy. These kids, they are so deep into it. So, I send out a questionnaire and ask them how they come, you know, like how do they do they come in groups to come by train? Are, they are, they just doing their job of pick up by it, by parents? Do the parents, they, they knew it. Exactly. And they came back with a really exact picture of what I was expecting. If you ask if you go for a Depeche Mode crowd or for, for, for, for the Rolling Stones crowd, you don't get this information, you know, and if, if there could be something. Yeah, I'd go with something. I don't know. I cannot even imagine that gives me that information. More information from Traffic Management Centre. So more, more information from the public transport and more exact numbers of people on the trains. When we were talking to our public transport on, on, on the football issues that we had. And we had a meeting as long years ago, but we had a meeting and I asked them how to me, how many people do you do you transport per train? And they said, well, the train has about four hundred fifty capacity. And I said listen what from what I can see every Saturday and Sunday, there are much more than. You know, we calculate calculated four people a square metre. That's it. I said, yeah, but that's not what you do. It's like you open the doors and you have six or seven people a square metre in those trains. They said, alright, yeah. Well, well, we don't know. I don't know about that. Well maybe, maybe should, we should have a look at it. You know, like that's, that's, that's the, that's the quality of, of data that we have that we're dealing with. And I would really love to, I would really love to change to change that data quality somehow. I don't know how, but that would be that would be brilliant. And all the approaches on, on Bluetooth and, and mobile phones, it's, it's nice, but it's from my perspective, it's not too much reliable because, you know, like, if you don't have a big enough number of people using that, it's the same with the apps and stuff. And we don't know. Right enough. That's the question. That might be a million in there might be a million people around or three hundred thousand and but fifteen thousand used. Yeah. OK, yeah. All right. So, what does it you know, like the data is, I cannot, I cannot use it somehow but I would.

I would love to. OK, closing, closing the last mile, the gaps in the last mile, that would be something really good.

Researcher: OK, so thank you. These were my questions, I'm not sure you would like to add something or maybe you have a question for me. I don't know.

R#06: I think it's more or less is very clear. I'm really interested in the outcome of...

Researcher: The document will be public once it's installed in that university. So, I'll make sure you get, you got a copy.

R#06: No worries. I would be. That would be great. And do you how many how many interviews will you do?

Researcher: Well, I intend to do eight, but at least six. And I would like to do eight. And then my time. But time is running out. I think so, yeah. In best case would be eight start.

R#06: Yeah. I would be interested in my will. You will, you will have it in your, you will have it in your system and I would be interested in, in well you know when we were talking about the opinions and how do we look at it, I would really be interested in the results. It's really, really looking forward. If I if I'm. How many did you before, already? you do?

Researcher: I think your number… I have to, I have to think you… you're number six.

R#06: It's getting late.

Researcher: So, I would like to do two more tomorrow. But I'm, I'm dependent on the, on the, on the agenda or calendar of my respondents, so to speak.

R#06: And what you say, what you say that I'll do. The others have different very different opinions on that.

Researcher: Or I think the, the, that, that for now the as good as I can remember, that the idea is bit the, the same. There are some differences in in how exactly tools are used. Some people tend to go more for the software ICT tools, other others are more to the pen and paper stuff. But in the end the tools are the tools to go for a means and in the end the means are all the same. So, let's see what, what comes out when I study in detail. But I think in general, for now, there is no big surprises actually, or

R#06: So I'm not doing everything wrong. So that's, that's, that's a good point for.

Researcher: I'm sure. I'm sure. You know,

R#06: I'm really looking forward for the for your thesis and the results that you come up with and really interested in.

Researcher: OK, I'll make sure you get you got a copy once it's in. Thank you. Thank you for your, for your time. And I'm sure we'll see each other whenever we can travel again and go to conference and stuff. So, thank you.

R#06: That would be great. Good luck to you, for you, for your, for your work and let me know how it goes on. OK, thank you very much. OK. OK everybody.