

Designing for Crowd Well-Being: Current Designs, Strategies and Future Design Suggestions

Jie Li*, Huib de Ridder**, Arnold Vermeeren***, Claudine Conrado****, Claudio Martella*****

**Ph.D. Candidate, Faculty of Industrial Design Engineering, Delft University of Technology,
The Netherlands, J.Li-2@tudelft.nl*

***Professor, Faculty of Industrial Design Engineering, Delft University of Technology,
The Netherlands, H.deRidder@tudelft.nl*

****Assistant Professor, Faculty of Industrial Design Engineering, Delft University of Technology,
The Netherlands, A.P.O.S.Vermeeren@tudelft.nl*

*****Senior Scientist, Thales Nederland B.V., Hengelo,
The Netherlands, Claudine.Conrado@d-cis.nl*

******Ph.D. Candidate, Department of Computer Science, Free University of Amsterdam,
The Netherlands, claudio.martella@vu.nl*

Abstract: This paper introduces the concept of crowd well-being and the needs for sustaining it. Crowd well-being can be interpreted as crowd members' evaluations on their emotional reactions, moods and judgments they form about their satisfactions, goals or needs fulfillment in a crowded situation according to the definition of subjective well-being by Diener and his colleagues. Higher level needs, i.e. relatedness and autonomy in Sheldon's two-level hierarchy are essential to the enhancement of crowd well-being when safety is guaranteed. Needs for safety become prominent in case of emergencies. Furthermore, it investigates three representative crowd management designs and strategies and how they fulfill the needs of crowd members through ten crowd expert interviews. We conclude that the current strategies and designs mostly focus on the effortful planning and preparation for the potentially unsafe situations, which tend to be coercive instead of fully respect crowd members' autonomy. A number of technologies are applied to monitor the crowd behaviors externally due to the security concerns rather than approach and assess them locally, understand their needs and provide real-time feedbacks to support their well-being. We suggest that future designs should allow the measuring to go into the crowds and place an emphasis on improving crowd members' higher level needs on the premise of security.

Key words: *crowd well-being, crowd management strategies, design for crowd*

1. Introduction

Have you ever waited endlessly in queues? Have you ever desperately trapped in a crowd? Have you ever lost your companies in the crowds and could not find them back? At that moment, were you feeling frustrated about wasting time, feeling angry about inability to escape or feeling helpless since your friends or family members are not reachable? All these happen frequently on this increasingly crowded earth. Public transportations have multiple peak hours every day. Large-scale recreation events are prevalent everywhere. Crowd experience becomes an inevitable component of daily life. Therefore, maintaining well-being in the crowds is an indispensable contribution to everyday well-being.

Crowds exhibit highly complex behaviors driven by individual goals, influence of other crowd members or the environmental factors. Crowd experts have put a great effort on developing designs and strategies to facilitate the movement and enjoyment of people. However, a crowd manager joked during the interview, “Our (management) system is perfect. The only problem is the crowds!” which reveals the difficulty in managing crowds. So far, there has been no prominent scientific paper on crowd well-being. A few guidebooks from the government in UK, US and China are widely used as the bible of crowd management. The most comprehensive guidebook is called Purple Guide or The Event Safety Guide from UK [7]. It covers almost all the frequent scenarios of crowd events, and the whole book is like lists of memos about the preparation of all kinds of big events. But crowd management is more than just following a recipe and preparing. There are a lot of changes and unexpected things during the event. Therefore, the real-time monitoring and predicting is the most difficult part for crowd managers.

Another prevalent trend is that our life is facilitated by the combination of sensor technologies and pervasive computation and communication such as wearable sensors, ubiquitous Internet and mobile computing. These technologies are becoming more and more invisible today, “waving themselves into the fabric of daily life” [19].

Combining the above technological trends and the social phenomenon, the idea of how to non-intrusively support the continuous well-being of individuals in crowded situations was generated by Project EWiDS¹. The goal of EWiDS contains two aspects: one is the development of a distributed sensing system and the other is a better understanding of crowd experience and how to design for sustaining crowd well-being with the aid of technology. Thus, this paper specifically focuses on examining the current crowd management designs and strategies through crowd expert interviews and attempts to evaluate their performances in fulfilling the needs that construct crowd well-being. In Section 6 of this article, future design suggestion is given based on EWiDS distributed sensing system.

2. Crowd Well-Being

Researches on the well-being topic are prevalent across disciplines, resulting in various implicit definitions. Pollard and Lee claimed to identify five distinct domains of well-being in their literature reviews, namely physical, psychological, cognitive, social and economic [11]. So far, the studies of well-being have primarily focused on the subjective and individual level. Subjective well-being (SWB) is a dominant key word in the well-being field, because researchers believe that subjectivity can better reflect individual’s unique experience. Diener proposed four factors that influence SWB. They are domain satisfactions, life satisfaction, pleasant affect and unpleasant affect. Compared to life satisfactions and domain satisfactions, affect, which consists of moods and emotions, reflects people’s instantaneous reactions. Pleasant affect includes *joy, elation, contentment, pride, affection, happiness and ecstasy*. In contrast, unpleasant affect refers to *guilt and shame, sadness, anxiety and worry, anger, stress, depression and envy* [3]. Apparently, pleasant and unpleasant affects are related to well-being in a crowded situation due to their short-term characteristic. In addition, Diener stressed that merely avoiding unpleasantness is not sufficient for enhancing SWB. SWB does not completely exclude unpleasant affect. In order to sustain SWB, the positive affects should exceed the negative ones [3].

What is crowd well-being? Crowd well-being is a special type of social contexts, which are crowded situations, with particular influences on individual SWB in the crowds. A crowd is not simply the sum of the individuals who compose it, since crowd members tend to influence each other and a crowd may display behaviors or

¹ EWiDS Stands for Extreme Wireless Distributed Systems. It is one of the projects under COMMIT, a leading Dutch research community in the field of Information & Communication Technology (ICT). EWiDS is concentrating on developing extreme wireless distributed systems, and are interested in crowd management as the application domain.

characteristics that differ from the individuals in it. Negative ideas, suggestions, emotions or judgments by some crowd members can spread out and get others infected as well [6, 8]. This negative contagion will certainly affect crowd well-being. In other words, people are socially connected, whose well-being does not only build upon their own needs fulfillment, but also be influenced by the needs fulfillment of others around them [2]. According to the definition of SWB by Diener and his colleagues [4], crowd well-being can be interpreted as crowd members' evaluations on their emotional reactions, moods and judgments they form about their satisfactions, goals or needs fulfillment in a crowded situation. Similar to SWB, maintaining crowd well-being should also guarantee the crowd members' positive experiences surpass the negative ones.

3. Crowd Types and Needs for Sustaining Crowd Well-Being

Needs fulfillment does make contributions to a person's feeling of well-being [16]. But what are these needs? Are they included in Maslow's 5-level hierarchy of needs? Or do they fit well to Sheldon et al.'s 2-level hierarchy of needs [14], which derive from several prominent need theorists, including Maslow, Ryan and Deci etc. Sheldon's hierarchy does not set a specific order for the four needs in the upper level, because he found their importance varies in different contexts, e.g. South Koreans rated self-esteem higher than Americans [14]. The physiological needs that are placed at the ground level in Maslow's pyramid are no longer perceived as basic necessities in the modern society, since people hardly experience urgent hunger nowadays. Needs for food and drinks are usually stimulated by appetite or pleasure rather than extreme hunger [10]. In spite of these differences, Maslow and Sheldon both agree that guarantees for safety and security are the premise before the needs for autonomy, competent, relatedness and self-esteem become prominent. Steere [15] used a pyramid to describe Maslow's five levels of needs (Figure 1a). Comparably, another pyramid was applied by the authors of this article to describe Sheldon's two-level hierarchy of needs (Figure 1b).

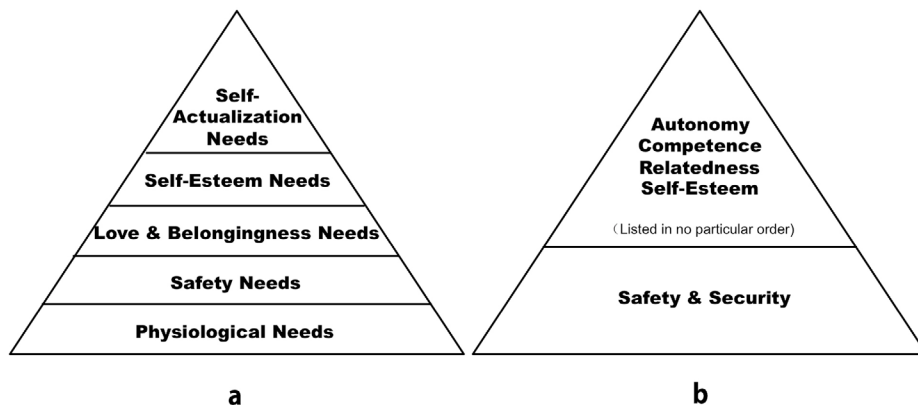


Figure 1. a) Maslow's hierarchy of needs described in a pyramid by Steere,
 b) Sheldon's new hierarchy of needs described in a pyramid by authors of this article

No matter which list of needs is more important, it is no doubt that all these needs are somewhat independent from each other and all have unique contributions to well-being. Thus, people have to fulfill a variety of needs and balance them well before they can achieve optimal well-being. These needs to well-being are very much similar to the vitamins to our body [10].

In a previous study, we carried out two focus group discussions with a total of 10 participants who had experience in crowds, as the starting point to approach the human needs that construct crowd well-being [9]. The goal of the focus group studies was to gather rich qualitative data and extract the needs that contribute to crowd well-being. Understanding the actual needs for maintaining well-being of crowd members serves as the criterion for examining the current crowd management designs and strategies in Section 5 of this article.

The participants of focus group studies were asked to name as many as possible the “crowds that attract you joining (attractive crowds)” and the “crowds that you want to avoid (unattractive crowds)”, as well as the reasons for joining or avoiding the crowds mentioned by them. They were also required to draw or write down their activities or experiences on two timelines, from entering a crowd until leaving it. One timeline was for experiences in an attractive crowd and the other was for an unattractive crowd. In the end, all participants presented their expectations in sustaining well-being in their self-made collages.

We found that crowd well-being needs are not consistent in all crowded situations. In consistency with Sheldon’s study [14], relatedness and autonomy are the two primary needs when people are in attractive crowds (crowds that attract people joining), which prove that crowd well-being is on a social level. People want to have a balance between feel included in the crowds and stay independent as an individual.

Security does not contribute to the improvement of crowd well-being, but definitely the most prominent needs when the crowd is getting out of control. That is the reason why people are more anxious about security issues when they are trapped in unattractive crowds (crowds that people want to avoid). Furthermore, the needs for pleasure (e.g. have fun, want to relax, etc.) are frequently mentioned as well. It is one of the most considered reasons for a crowd becoming attractive and at the same time, lacking it is one of the most mentioned reasons for people to avoid the crowds.

Besides, we identified that crowds are either event crowds or non-event crowds. An event crowd is always event-based. People join the crowds for the performances or the activities in that event, e.g. concerts, dancing, fireworks, exhibitions etc. or because they want to interact with the people in the crowds, e.g. conferences, family or friends gatherings, parties, etc. Event crowds exist for the crowds. Imagine if there are no crowds, it is not necessary to have big festivals. An non-event crowd usually does not involve any performance, people presenting is not because they enjoy the crowds, but want to achieve some external goals or receive some benefits outside the crowds, e.g. crowds at public transportation, crowds waiting in queues for free goods, etc. The non-event crowds are not always involving big crowds. For example, the trains will continue operating even there is no people on the platform. Similarly, a crowd can be further seen as a series of event moments and non-event moments. For example, squeezing through the entrance, waiting in queues are non-event moments, but meeting and chatting with friends, enjoying the show are event moments.

Generally, event crowds are mostly regard as attractive crowds and event moments are mostly regarded as positive moments, where people tend to search for relatedness, autonomy, pleasure and benefits and need for security is hardly mentioned, since an attractive crowd usually guarantees the security. In contrast, non-event crowds and non-event moments are mainly counted as unattractive and negative, where the negative experiences exceed the benefits they are looking for. So crowd members are more anxious about security issues and want to stay informed about the situation and possibilities to escape [9].

The main findings in focus group studies are summarized in Table 1.

Table 1. Summary of focus group findings

Crowded Situation	Attractive Crowds (Crowds that attract people joining)	Unattractive Crowds (Crowds that people want to avoid)
Characteristics of the Crowded Situation	<p>-Event Crowds (Event crowds are event-based. People join the crowds for the activities, e.g. concerts, dancing, fireworks and exhibitions.)</p> <p>-Mostly Well-Behaved Crowd Members (People see these crowded events are well organized with a majority of well-behaved people and thus feel safe in attending them.)</p> <p>-Positive Experiences Exceed the Negative Ones</p>	<p>-Non-Event Crowds (Non-event crowds usually do not involve any performance or interesting activity. People presenting is because they want to achieve some external goals or receive benefits outside the crowds, e.g. crowds at public transportation, crowds waiting in queues for free goods.)</p> <p>-Visibly Misbehaved Crowd Members (People in unattractive crowds are more anxious about safety issues because they usually witness some misbehaved people.)</p> <p>-Negative Experiences Exceed the Positive Ones</p>
Needs of Crowd Members for Sustaining Crowd Well-Being	<p>-Relatedness (Have a sense of belongingness, e.g. stay with friends and network with crowd members)</p> <p>-Autonomy (Feel free, stay informed about the activities and have control over oneself)</p> <p>-Pleasure (Look for fun stimulations)</p> <p>-Benefits Motivated (Look for benefits, e.g. gain knowledge in exhibitions or conferences)</p>	<p>-Safety (Needs for safety become prominent because people feel less secure.)</p> <p>-Information (People want to stay informed about the situation, e.g. waiting time, and the possibilities to escape)</p>
Goals for Sustaining Crowd Well-Being	<p>-Enhancing the support of crowd members' needs for relatedness, autonomy, pleasure and benefits.</p>	<p>-Enhancing the (feelings of) safety</p> <p>-Providing predictions about the situation</p> <p>-Changing the non-event crowds into event crowds to introduce more positive experiences (e.g. introducing fun elements, e.g. games, activities that could distract crowds)</p>

4. Crowd Expert Interviews

After the exploration of need constructs of crowd well-being in focus group studies, 10 semi-structured crowd expert interviews were conducted with three main goals. First of all, we emphasized on understanding the general process and methods of crowd management. Secondly, we attempted to find out the managers' main concerns on crowd management. In the end of each interview, we probed managers regarding the usefulness of distributed sensing technologies for crowd behavior understanding and tried to steer their storytelling toward the possible applications of these technologies. In this paper, we will not present the entire manager interview results. Knowledge about the existing crowd management designs or strategies and evaluations on whether they meet the needs of crowd members will be the emphasis.

4.1 Procedure

The interviewees are either crowd managers or professionals experienced in dealing with large crowds of at least 1000 people (Table 2). Each interview was scheduled around 1 to 1.5 hours at their work place and was recorded with a voice recorder. All the artifacts accessed in the interviews, for example, sketches, booklets, photos and maps etc. were collected. Although a list of questions was prepared according to the goals, all the interviews were done in a flexible style instead of sticking to the exact questions on the list. The interviewees were triggered to tell concrete stories rather than talk about general and abstract things. This semi-structured approach prevented the interviews falling into the question-response pattern and encouraged the raise of theme-related new questions that can adequately elicit the issues to compose a more comprehensive report [13].

Table 2. Ten crowd experts and their working contexts

Working Contexts of Crowd Expert	Crowd Size (Persons)	Crowd Duration
Indoor Music Festival	1700	6 hours
Indoor Conference	1000	12 hours
Central Train Station (on a celebration day)	250,000	4 hours
Police (on a celebration day)	700,000	8 hours
Security Company	1000-100,000	Several hours to days
Barrier Company	1000-100,000	Several hours to days
Outdoor Music Festival	60,000	3 days
Stadium	55,000	4-5 hours
Theme Park	40,000-60,000	12 hours
Train Station Flow Management	180,000	12 hours

4.2 Analysis

A creative on-the-wall method was used for analyzing the interviews [13]. The first step was to transcribe all the interview recordings into texts right after each interview. A team of three researchers read through all the transcripts and marked the interesting paragraphs. Decisions on which information should be put onto statement cards were made within the research team.

The statement cards consist of two parts: interpretations followed by selected quotes. In order to differentiate between interviewees, different colors of post-its or post-its with a diagonal line on the upper left corner were used to represent 10 different interviewees (Figure 2). The timing of the quotes was kept on the statement cards. So it is easy to trace back to the raw data.

Three researchers generated 241 statement cards in total. In the categorizing and pattern finding session, one more researcher in the project joined in to help with the pattern finding. There was no predefined category directing the sorting. Name of each category was emerging during the sorting.



Figure 2. An example of statement card (left) and color post-its representing different interviewees (right)

In the end, all the information can be grouped into three dominant categories. They are “preparation before the events”, “operational measures during the events” and “comments and expectations in the future”. Current strategies, designs and technologies are included in the first two categories.

4.3 Crowd Management and Crowd Control

It is necessary to distinguish crowd management and crowd control since the designs and strategies are different in them. According to Berlonghi’s definition, crowd management includes all measures taken in the normal process of facilitating the movement and enjoyment of people, while crowd control includes all measures taken once crowds are beginning to or have got out of control [1]. In other words, crowd management is proactive whereas crowd control is reactive. The differences of these two concepts have been stressed by most of the interviewees as well. From their responses, crowd management involves analyzing and predicting for potential problems and preparing for all phases of a crowd event beforehand and acting according to the prepared scenarios during the event. Crowd management at least starts half a year earlier than the event. As the manager of a stadium said,

“ Actually there are four levels in dealing with crowds, in my point of view. The first is the preparation, which is part of crowd management before the events. Then we have crowd management according to the prepared strategies during the events. The third is crowd control. The last one is more extreme than crowd control, called riot control. The first two levels take most of the efforts. The last two are backup strategies, which allow police to use violence and only account 10% chance to happen. The rest 90% is our (crowd managers’) responsibility. Preparation and crowd management before and during the events, e.g. everything about monitoring crowd behaviors, implementing rules and distributing crowds are our tasks. Coordinating the stewards and the security personnel are also our tasks. Only when the crowd is getting out of control and there is something concerning public order or incidents, the police step in and take over.”

The designs and strategies in crowd management vary from site constructions to scenario predictions. In crowd experts’ opinion, crowd management takes most of the effort in supporting crowds and helping them stay as comfortable as possible. Usually, the police step in for crowd control, or in extreme situations, called riot control, which has a low chance to happen (Figure 3). Crowd management is persisting. Even during crowd control, it is still operating to assist the police. For example, when police is dealing with some mobs in one area of the event, crowd managers are managing the rest of the crowds. That is the reason why the majority of the current designs and strategies are focusing on crowd management.

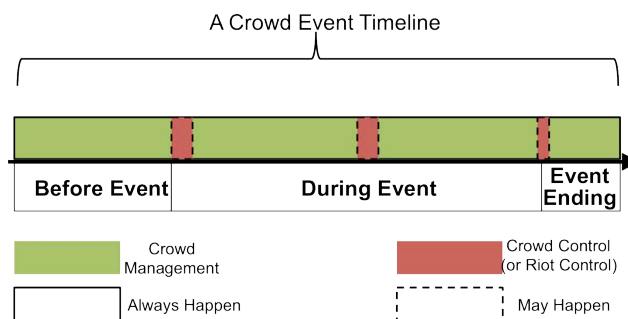


Figure 3. Crowd management versus crowd control/riot control

5. Evaluating three Representative Current Crowd Management Designs and Strategies

In this section, we select three representative crowd management designs and strategies applied by crowd experts and evaluate whether their performances meet the needs of crowd well-being described in Section 3 of this article.

5.1 Barriers

Barriers are the most common facilities in crowd management. Three most frequently used barrier shapes are illustrated in Figure 4. The traditional barrier lines for short-time queuing are often seen in airports or outside famous museums. As can be seen in Figure 4a, people are queuing up in a single line, which means, if you have urgency, e.g. you are hurry for toilet and you jump out, then somebody will take over your position. It is impossible for you to find back your position since this is a short-time queuing and people are moving constantly. The 5-meter barrier sections are usually applied for long-time queuing, e.g. for the enthusiastic fans who are waiting outside the concert hall half a day before the concert starts. The visitors are divided into manageable groups that can fit into a 5-meter barrier section. The barriers are not very high and people are allowed to jump out to toilet or buy food. They can go back to the section he or she belongs to because people are not standing in a single line or moving forward. People in the same section forms an autonomic group. They more or less recognize people’s face in their group. They will not allow people outside their group to go into their queue section (Figure 4b). The third interesting shape is called bone-structure barrier line, which is frequently seen in large concerts. They divide the whole field into chambers and leave enough space for service personnel walking inside the crowds. Once emergency happens, the police, security guards or doctors can easily go into the crowds. People

tend to push forward during the performances, this bone structure can largely stop the pushing domino effects and reduce the pressure given to the crowd members in the front. The soft fences around the field can be pushed over easily, which allow people to evacuate from all directions in very short time (Figure 4c).

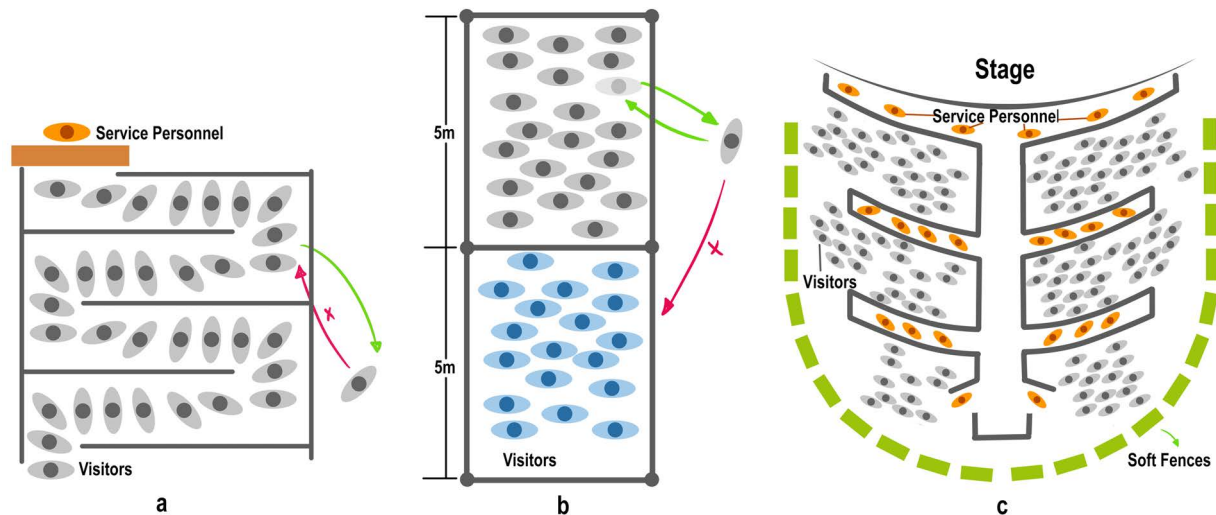


Figure 4. a) Traditional barrier lines for short-time queuing, b) 5-meter barrier sections for long-time queuing and c) bone structure barriers in front of a stage

According to Tromp et al.'s four types of product influence, i.e. coercive, decisive, seductive and persuasive [17], the traditional barrier lines are rather coercive. They shape people's queuing behaviors and guarantee the safety. However, they neither support autonomy needs nor introduce the connected or related feeling to the crowd members. People in this situation feel detached from each other. They do not have high expectations for staying comfortable and interested. All they want is to move forward as fast as possible. This type of barriers is frequently used in non-event crowds, e.g. queuing at airport, where the security needs are more prominent than needs for belongingness or autonomy in maintaining well-being.

The 5-meter barrier sections are more advanced. Even the barriers themselves are coercive to force people to divide into groups. They support people's autonomy. The norms are generated spontaneously inside the groups. People are more related to each other in the same group. For non-event crowds, this type of barriers is usually used for long-time waiting, which ensures crowd well-being through fostering the belongingness within the crowd members.

The bone-structure barriers are between coercive and decisive, since they do not block people completely, although they do prevent people from coming too close to the stage. People leave the space for service personnel automatically without feeling being forced. It is a more respectful way to shape crowd members' behaviors. This type of barrier system significantly enhances the safety, because security personnel are always at a reachable distance inside the crowds. It also enables crowd members to evacuate in all directions because the soft fences can be easily pushed over, which ensures that the evacuation can be done in a minimum amount of time. However, it does not provide notable support for higher needs for improving crowd well-being in event crowds.

5.2 Stadium

For the stadium we visited, they usually place matrix boards at the exits of the highways to tell people the proper exit to take several hours before the event starts. For example, if you should directly leave at Exit A10 or you should take a detour to Exit A2 in order to easily find a parking place and the entrance written on your tickets.

Besides this, they also define special section for different groups of people. For instance, there is a special section for people coming by public transportations. A path is built to connect the public transportation to the section in the stadium. There are also special sections for families or other people who have similar interests.

The matrix boards at the exits of highways are persuasive strategies. They provide suggestions, but still respect people's autonomy. The special path connecting to the stadium is decisive, which provide convenience to the people who come by public transportations non-intrusively. The compartmentalizing inside the stadium helps the family members and people with similar interests stay together. All these measures, at the lower level, support crowd well-being by ensuring the security; at the higher level, help people feel included in crowds and autonomic in decision making.

5.3 Bluetooth Tracing and Camera Counting

Some stations or ticketless events use devices to pick up Bluetooth or Wi-Fi signals from the smartphones in the crowds in order to roughly estimate the amount of visitors. They claim that, on average, 1 out of 12 or 14 persons will turn on the Bluetooth on his or her smartphone. Camera counting serves the similar purpose as the Bluetooth devices. The smart cameras can estimate the amount of people by counting the heads appearing in the camera.

These two designs both experience problems in practice. Most people are reluctant to turn on their Bluetooth, especially in a festival that lasts for several days, because Bluetooth consumes a lot of battery energy (Figure 5b). That is to say, the Bluetooth ratio 1:12 or 1:14 is not always true, which fluctuates significantly in different crowds. For example, the smartphone ownership in crowds of the elderly may significantly differ from that in crowds of the young people. The cameras can mistakenly count 2 or more people as 1 when people are closely packed together (Figure 5a), which may largely influence the accuracy of the estimation. The aim for estimating the amount of people is to guarantee that the crowd density is within control and does not really pay attention to fulfill people's needs that could enhance crowd well-being.

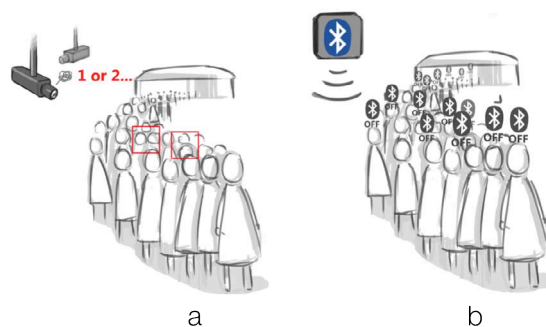


Figure 5. a) Camera counting mistakenly counts 2 persons as 1 when crowd density is high; b) people are reluctant to turn on Bluetooth due to the high energy consumption

5.4 Conclusion of the Evaluations

Many drawbacks can be identified in the current crowd management designs and strategies for supporting crowd well-being. First of all, most of them tend to be coercive and intrusive to ensure the safety and order instead of supporting autonomy and individual decisions in the crowds. Secondly, most of the crowd information is gathered from the external devices that monitor the crowds from an outsiders' view. Therefore, the gathered information is inclined to be behavioral or objective rather than psychological or subjective. In other words, this outsiders' view may merely direct crowd managers' attention toward crowd density or abnormal crowd behaviors

and induce managers to put all the effort on safety issues. Crowd members’ higher level needs, such as staying in crowds as an independent individual, continuously feeling welcomed by a group, and feeling respected and taken care of, etc. may be overlooked.

Notably, several crowd managers claim that they spend a lot of the efforts on long-term preparation and prediction before the event. They plan for all the thinkable situations. However, no matter how well prepared beforehand, it is still impossible to completely avoid incidents during the event. So far, we have not seen designs that can efficiently support real-time management, which enable managers to always have an overview of the situation and accurate predictions of the crowd dynamics far before the critical moments. So they can have sufficient time in developing strategies on the spot for maintaining and improving crowd well-being. This is a gap, but also a challenge and opportunity.

6. Future Design Suggestions based on EWiDS Distributed Sensing System

In the future, the definition of crowd management should to be broadened. That is to say, crowd management is not only the efforts on well preparation beforehand and measures taken according to the prepared scenarios, but also flexible real-time strategies based on situation awareness [5]. The goal is to enable crowd managers to know in advance about how a certain situation is likely developing from the subjective well-being reports from the crowd members, thus help them act accordingly as early as possible. For instance, they would like to have an estimate of how soon a place will get overcrowded, how people feel in the crowds and how early the feedback should be given to the people to handle the situation and keep crowd well-being.

Furthermore, merely external monitoring may get a clue on crowd behaviors, but is far from sufficient for understanding crowd needs. As suggested in Li et al.’s study, designing for crowd well-being should pay more attention to improve higher level needs of crowd members rather than merely focus on guaranteeing the crowd safety [9]. Therefore, going into the crowds, assessing them locally and non-intrusively, allowing crowd members to feed forward their subjective feelings about the situation, understanding crowd needs and providing real-time feedbacks to support these needs are the future design trends for crowd well-being. EWiDS project is following this direction, which aims to design a distributed sensing system both for large-scale crowd management as well as steering social interactions in smaller scales [18]. This system will include three main components, 1) a basic node that can detect and communicate with other nodes in its proximity across a large-scale network, 2) multiple sensors connected to sensor node that can pick up crowd information like sound, movement, temperature, etc. 3) a local hub, typically a smartphone both connect basic node and sensors for local data processing and storage, which is also a nice interface for providing feedbacks to users and gather subjective reporting from users (Figure 6).

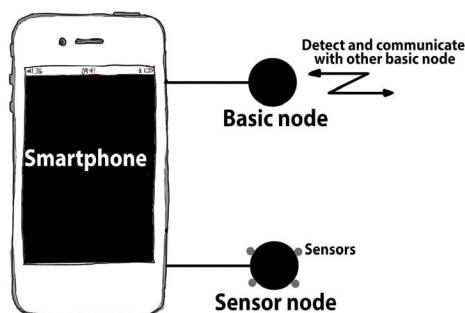


Figure 6. Designing distributed sensing system in EWiDS

With this system and proper sensors, we expect to understand crowds from an insiders' view. Apart from giving crowd managers a better overview of crowd density and flows, this system can also sustain crowd members' higher level needs by providing them with constant feedbacks about the situation, which enable them to make self-decisions and feel connected in crowds. These are essential for improving crowd well-being. One example is to extract the key words of group discussions in a conference. So the new comers are able to select which group is closer to their expertise and their needs for autonomy (i.e. be able to make self-decisions) and relatedness (i.e. feel included in the right group) are fulfilled.

With the smartphone interface, crowd members can receive customized guidance. They can also report real-time information to help managers or other crowd members. For instance, crowd members can be asked to report the emotion of themselves and that of the crowds around them from time to time. Combining with location information, a real-time map of crowd emotion can be generated by crowd members' reports, which can alert the manager when the negative emotions are popping up in some areas, indicating the crowd well-being is decreasing. So crowd managers can take measures to control these negative seeds in time. This real-time emotion map can also make crowd members be aware of where the happy crowds are. In these cases, crowd members are actively participating in crowd management. They feel respected and no longer blindly follow the instructions or forced to change some behaviors. They become more autonomic and competent, and feel related to the other crowd members and even crowd managers.

7. Evaluations of EWiDS System

Some crowd experts pointed out that EWiDS distributed sensing system would be very useful in non-ticket events, where the amount of visitors was unpredictable. They believed that this system would largely improve their efficiency in communicating with crowds. But how to implement this system in large crowds is not clear, e.g. how to hand out the sensors, persuade people to use them and protect their privacies.

According to the interview findings, EWiDS system should not focus only on providing real-time assessment of a situation like what the current surveillance cameras do, which is problematic when the situation is already critical. Emphasis should be placed on monitoring changes in crowds, which give insights into tendencies. In addition, psychological aspects such as the crowd moods or emotions are of utmost importance. Crowd managers explicitly expressed their needs for mechanisms that would allow accurate estimation of crowd mood. Finally, crowd managers like the idea to enforce the establishment of connections between people in crowds. This could be done to help people find back friends or family members that got lost in a big crowd, as well as promote people's networking, e.g. by bringing together people with common interests.

8. Acknowledgement

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