Safe environment for pedestrians participating in public events

V Bukhtoyarov¹, S Dorokhin¹, V Ivannikov¹, A Shvyriov¹, K Yakovlev¹

¹Voronezh State University of Forestry and Technologies named after G.F. Morozov, 8, Timiryazeva Str., Voronezh, Russia

E-mail: dtn.prof@yandex.ru

Abstract. Ensuring comfortable and safe conditions for visitors to large-scale events of various kinds is one of the priority areas for the organizers. There are many examples when insufficient attention was paid to security issues, which led to sad consequences for the audience. Mistakes in planning evacuation routes in emergency situations are the main cause of panic for a crowd of people. Victims of the evacuation can be avoided with a well-organized system of informing the audience and a pre-planned visual orientation with signs and arrows, as well as sound. Visitors should be instructed and aware of the routes and exits that should be used in case of emergency evacuation. This article discusses the possibility of creating the necessary prerequisites for improving the safety of pedestrians participating in mass events. The presented study is aimed at forming the necessary foundations for developing recommendations to improve the safety of events with a large number of participants.

1. Introduction
Every day, people all over the world make millions of movements from one point to another, using various types of vehicles or walking. To provide for it, various objects of transport infrastructure are designed, built and constantly improved. In most cases, the introduction of new and reconstruction of existing structures is aimed at achieving the following range of tasks:
- increasing the speed of vehicles, which is explained by the need to obtain the greatest economic effect from their operation;
- cutting energy costs, as well as the time of passengers or goods transportation;
- reducing environmental pollution by harmful emissions from vehicles.

The issues of ensuring the safety of road users and especially pedestrians when designing and constructing road interchanges and other infrastructure are often considered secondary. It leads to an increase in the number of conflicts in these facilities when pedestrians crossing the roads [1]. As practice shows, in the vast majority of cases, priority is given to high-speed automobile traffic and pedestrians are forced to lose time when crossing highways due to the large distance between regulated pedestrian crossings or violating traffic rules to create emergency situations on the road (Figure 1). To eliminate such incidents, one of the key aspects in the organization of road traffic should be the creation of conditions for increasing the mobility of pedestrians and ensuring their safety in pedestrian traffic.
2. Discussion
Pedestrian mobility research is currently expanding in areas such as transportation, urban planning, and healthcare [2,3,4,5]. Part of these studies focused on characteristics of an urban environment conducive to pedestrian traffic and an increasing number of studies were aimed at studying the level of pedestrian service, while less interest was shown in studying the quality of pedestrian service. The quality of service is determined as a result of pedestrians' perception of walking conditions and is formed by attributes associated with it. This perception depends on personal and socio-economic preferences of the pedestrian, as well as the purpose of the walk.

At large sporting events, when many people move at the same time, meeting transport needs is critical to its success and mitigating the impact on cities and mobility. Public transport systems are best suitable to meet these needs and transport policies should aim to promote these mechanisms. However, other means of transportation are also used and walking is the preferred option if the destination is within a reasonable distance and city conditions are suitable.

The quality of transport service can be defined as the passenger’s perception of how well the service or facility is functioning. It is formed by the attributes associated with the trip, and therefore provides aggregated information about the quality characteristics directly perceived by users, which often correspond to the reasons for choosing the type of transport [6]. According to [7], perception is responsible for establishing a relationship between the physical characteristics of the environment and the behavior of pedestrians.

Since they relate to the context of perception, the characteristics are subjective and intangible in nature, which makes their determination difficult. The perception is how external stimuli are selected, organized and interpreted by each individual. In transport practice, these stimuli can be considered as a set of variables representing each attribute of service quality. Variables are tangible elements that directly or indirectly affect the quality of the pedestrian environment through the perception and senses experienced by each pedestrian [7].

Pedestrian accessibility research tools developed in recent decades to assess the quality and accessibility of infrastructure for pedestrians are numerous. These studies are often aimed at checking the technical quality of road infrastructure in order to determine its compliance with established standards.

Regarding the technical quality of the pedestrian environment, another aspect should be highlighted here and that is the relationship between the city structure and models of walking trips. Since the 1990s, approaches like new urbanism, smart growth and transit-oriented development have become more sustainable alternatives to urban development involving high population density, mixed land use, well-connected street networks and public transportation [8]. According to various researchers, this urban model favors walking and reduces dependence on cars. Based on these assumptions, many density indices were created with the aim of measuring by means of characteristics of the built-up environment and the ability of a place to stimulate walking as an effective way of moving.
Another popular method for assessing the quality of the pedestrian environment is the level of service. This concept is often confused with the quality of service, despite the presence of various aspects. According to the Guidelines for Highway Capacity [9], the level of service is a quantitative indicator determined from a set of technical indicators used to measure various aspects of operation, therefore, unlike the quality of service, this method does not take into account the perception of users. The purpose of determining the service level is to measure productivity and the relationship between infrastructure supply and pedestrian demand.

In this sense, although the characteristics of the built environment and road infrastructure affect the quality indicators perceived by pedestrians, the assessment of these parameters differs from the assessment of quality associated with perception like a sense of comfort, safety or convenience [7]. The behavior of pedestrians is better understood through a thorough analysis of perception than through the objective characteristics of a built environment. Therefore, the quality of service can be considered as a quality measure that has a peculiar character, since its assessment depends on the personal and socio-economic characteristics of pedestrians and characteristics of the trip [6].

There are some characteristics that define it in the literature on the quality of transport services. This is accessibility, reliability, comfort, convenience, speed, reliability and safety. In the case of pedestrian walks, sociability can be added to these characteristics, which, although it has been little studied, stands out in studies on walks as recreational activities.

In the case of walking, in addition to being a means of achieving a specific goal, walking is also a form of exercise and a recreational activity. When pedestrian walks are aimed at fulfilling the second goal, indicators such as comfort, reliability, convenience and sociability are generally more valued by pedestrians. However, when the goal of walking is to reach the final destination within a given time, such moments as accessibility and speed are generally valued higher. Safety features are considered essential for all walking purposes.

As for walking with the aim of accessing sporting events, the quality of pedestrian services has not yet been adequately studied and there is no way to determine the indicators that stand out in this context. Despite the fact that such walks have rather unique characteristics, especially when they are preceded by world-wide events, such components as the cost of the ticket, the importance of the event, the socio-economic profile of the audience and the type of transport strategy developed by the local authorities will directly affect the preference of walking trips.

3. Ensuring the safety of participants in public events
As previously noted, the second component when choosing a method of transportation to events is the safety of travel routes and stay in crowded places. Recently, there has been an increased interest of researchers in studying issues that explain the flow behavior of pedestrians in emergency situations. It is found that to study the mobility of people in case of panic situations, it is necessary to analyze the principles of crowd dynamics and collective human behavior. Knowledge of crowd dynamics is necessary for the design of sports arenas, exhibition venues, transport terminals, large performances, etc.

To reduce risks, it is necessary to carry out a number of organizational and technical measures, such as developing an evacuation plan to safe places, conducting specialized trainings for personnel in organizing events, preparing sites for the movement of emergency vehicles and obstacle-free escape routes [10,11,12]. The focus of this work is on activities that logistics, architecture and engineering specialists can do to design emergency exits that are easily accessible and free of obstacles.

The importance of such events is justified by major emergencies at sports stadiums for various reasons, such as hooliganism, fires, structural breakdowns, terrorist acts and natural disasters. Analysis of the ten largest tragedies in football stadiums indicates that the greatest number of deaths occurs when people are crushed (trampled or pressed vertically) during the riots [13]. Developing a good emergency plan is essential in preparing for potential disasters, taking into account different scenarios, specific risks (in line with risk management) and complexity. Other important factors contributing to the development of an emergency plan are the preparation of specialized emergency teams and the
availability of a good emergency plan because it is not possible to train viewers in emergency situations. At the stage of danger, it is important to have a plan to evacuate the audience and to manage the presence of onlookers, which ultimately disrupt the work of emergency crews. It is also necessary to plan control over the movement of people, both inside and outside the crash site. Typically, these people have behaviors that can be expected, as they act like a crowd [14,15,16].

One of the most catastrophic forms of collective human behavior is the stampede of a crowd, often leading to death and serious injury when people are crushed or trampled upon. Panic theory deals mainly with factors that can lead to panic during emergencies. The basic premise is that when people face danger, their ordinary conscious personalities are often replaced by unconscious personalities that force them to act irrationally (Figure 2).

Under normal conditions, pedestrians move with ease, choosing the path based on factors related to his interests and environmental features. In general, the behavior of pedestrians is affected by their physical characteristics (age, gender, state of health, physical structure, etc.), traffic characteristics and track characteristics. Each person walks at a certain speed (free flow speed) and keeps a certain distance from other pedestrians and physical obstacles.

In panic situations, human behavior is completely different. People are more nervous and go much faster than usually. Individuals begin to press and interactions between people become frequent. Some people accumulate near the exits, and the phenomenon of the arch, represented by many people trying to get through a small hole, is a barrier. Escape is also slowed down by fallen or wounded people who become obstacles. People tend to show herd behavior, that is, to do what other people do, and in escape situations, alternative exits are often overlooked or not used effectively.

Panic can be caused by many factors, such as natural disasters (floods, earthquakes, volcanic eruptions) or man-made threats (fires, terrorist attacks, loss of social control by the state, etc.). Sometimes panic is provoked in life-threatening situations, such as fires in crowded buildings. Sometimes riots can occur for no apparent reason, for example, during a race for free places. In a panic situation, there is always a sense of impending danger and an urgent need to act. To understand panic in a crowd, several factors must be taken into account and they are as follows:

- in panic situations, people usually realize that their survival depends on quick decisions;
- the individual personality is weakened, so there is a change in the value system and a decrease in responsibility, which leads to the imitative behavior present in groups;
- there may be slogans, badges, uniforms, sound or rhythmic manifestations that reinforce group identity, rather than individual;
- people express a high degree of irrationality, worrying about the idea of escape and not thinking about the consequences of their actions.

Crowd forces in a panic case can reach levels that are almost impossible to resist or control. Most deaths in a crowd out of control are due to suffocation from squeezing. These forces are caused by the
action of pushing a person forward, creating a domino effect of people leaning on each other. People die from suffocation due to contraction their chests cannot expand for inspiration.

Some events gather a large number of people and even intense crowds, for example, big holidays, sports and religious events. Therefore, during such events, there is a high probability of outbreaks of panic and therefore evacuation should be carefully planned, including the architecture of buildings (Figure 3). In emergency evacuation situations, people usually move in the same direction. However, some participants may try to move against the direction of the evacuation, for example, to find their families or try to escape along a different route. Firefighters and other emergency personnel may also need to enter the building, which will cause significant interference with the flow.

![Figure 3](image.png)

**Figure 3.** The planned organization of movement of people during the holiday.

Studies of specific emergencies prove some features of crowd behavior that are very well described in the literature. In particular, it is noted that many doors are not used because they are poorly visible or poorly marked. This means that visitors often use the same path that they used before to escape and this creates congestion, bottlenecks and low levels of service. The organization staff who has been trained and is ready to provide assistance and quickly guide people to the best escape route provides significant advantages in terms of evacuation. The most anticipated effects are a better distribution of people in different exits and a reduction in the time of evacuation from the premises. It is possible to provide architectural solutions when designing and constructing buildings that will help ensure the rapid evacuation of spectators and personnel in emergency situations and allow them to carry out their activities in safety and comfort.

It is important that when organizing public events special attention should be paid to the availability of possible escape routes in the event of an emergency. According to reports of accidents that have already occurred in public gathering places, evacuation is a big problem, where many people are trampled and eventually die.

Therefore, building space should be mutually coordinated, obstacles and irregularities should be avoided in places where evacuation routes are going through, conditions should be created for good visual orientation and good communication with the fans so that the crowd can be controlled and directed in an emergency.

4. Conclusion

The practice of organizing mass events shows that although it is impossible to ensure complete safety, it is quite realistic to foresee the possibility of emergencies and develop the following preventive measures:

- the presence of the sufficient number of routes, walkways and wide enough doors for the quick exit of spectators of stadiums is important for the evacuation of people in a calm and safe way;
- the information system and a well-planned orientation with signs, arrows and sound warnings have a big impact on the dynamics of evacuation and, therefore, on safety;
- spectators and other users of stadiums should be well instructed in advance about the routes and exits that should be used in case of emergency evacuation, that will avoid panic caused by ignorance of how to be safe.

Further studies suggest an assessment of the effectiveness of the proposed preventive measures using computer modeling tools. The presented analytical study will also make possible to formulate the main areas of work, the purpose of which is to develop guidelines for ensuring the safety of participants when organizing and holding public events.

References

[1] Terentyev V, Andreev K, Anikin N, Morozova N, Simdiankin A 2020 *E3S Web of Conferences* 164 03042 DOI: 10.1051/e3sconf/202016403042

[2] Bezbradica M, Ruskin H 2019 *Smart Urban Developmen* DOI: 10.5772/intechopen.86801

[3] Bely O, Barinova L, Zabalkanskaya L 2019 *Transport: science, equipment, management. Scientific information collection* 8 13

[4] Evseeva A 2016 *E-Journal Public Administration* 59 238

[5] Ter-Voskanyan O 2018 *Academia. Architecture and Construction* 3 94 DOI: 10.22337/2077-9038-2018-3-94-99

[6] Florez J, Muniz J, Portugal L 2014 *Procedia - Social and Behavioral Sciences* 160 130 DOI: 10.1016/j.sbspro.2014.12.124

[7] Ewing R, Handy S 2009 *Journal of Urban Design* 14(1) 65 DOI:10.1080/13574800802451155

[8] Yassin H H 2019 *Alexandria Engineering Journal* 58 251 DOI: 10.1016/j.aej.2019.02.005

[9] 2010 *Highway Capacity Manual* (Washington, DC: Transportation Research Board, National Research Council)

[10] Kolomiytseva D, Konovalova T, Lazarev A 2016 *Scientific works of the Kuban State Technological University* 3 67

[11] Makarova I, Khabibullin R, Pashkevich A, Shubenkova K 2017 *Transportation Research Procedia* 20 430 DOI: 10.1016/j.trpro.2017.01.070

[12] Johansson A, Batty M, Hayashi K, Al Bar O, Marcozzi D, Memish Z 2012 *Lancet Infect Dis.* 12 150 DOI: 10.1016/S1473-3099(11)70287-0

[13] Melrose A, Hampton P, Manu P 2011 *Procedia Engineering* 14 2205 DOI: 10.1016/j.proeng.2011.07.277

[14] Berner A, Alharbi T, Carlström E, Khorram-Manesh A 2015 *Journal of Acute Disease* 4(1) 37 DOI: 10.1016/S2221-6189(14)60080-9

[15] Iryo-Asano M, Hasegawa Y, Dias C 2018 *Transportation Research Procedia* 34 67 DOI: 10.1016/j.trpro.2018.11.015

[16] Duives D, Wang G, Kim J 2019 *Sensors* 19 382 DOI:10.3390/s19020382