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Wayfinding and Evacuation in Stadiums: A Systematic Review of Spatial, Perceptual, and Crowd Management Factors

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Abstract

Wayfinding plays a crucial role in ensuring safe evacuation in complex, high-density environments such as stadiums. However, existing research tends to examine spatial design, human perception, and crowd management as separate domains, resulting in fragmented understanding of evacuation performance. This study presents a structured literature review to synthesize key factors influencing wayfinding in emergency contexts. The review identifies three major dimensions: (1) spatial and technical factors, including legibility, visibility, and signage systems; (2) human perceptual and psychological factors, such as decision-making under stress and behavioral responses; and (3) organizational factors, including crowd management and evacuation planning. The findings reveal that evacuation inefficiencies often arise from the lack of integration among these dimensions. This paper proposes a conceptual synthesis positioning wayfinding as a socio-spatial system, offering a more holistic framework for future research and design practice in stadium safety.

Keywords: *Wayfinding, Emergency Evacuation, Spatial Cognition, Crowd Management*

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INTRODUCTION

Emergency evacuation in stadiums presents a critical challenge due to spatial complexity, high crowd density, and time-sensitive decision-making. In such contexts, wayfinding becomes a key factor influencing how individuals interpret their surroundings and select routes to safety.

Previous studies have demonstrated that evacuation performance is influenced by architectural layout, signage systems, and environmental cues (Kaplan & Kaplan, 1982; Weisman, 1981; Arthur & Passini, 1992). However, these studies are often fragmented across disciplines such as environmental psychology, architecture, and crowd science. As a result, there is a lack of integrated understanding of how spatial, perceptual, and managerial factors interact during evacuation. This limitation is particularly relevant in stadium environments, where large crowds and complex circulation systems amplify the consequences of poor wayfinding design.

This paper addresses this gap by conducting a literature review to answer the following question:
What are the key factors influencing wayfinding in stadium evacuation, and how can they be integrated into a unified conceptual framework?

METHOD

This study adopts a structured literature review approach to systematically identify, analyze, and synthesize existing research on wayfinding and evacuation (Lin et al., 2020; Lin et al., 2023; Duan, 2024). This approach allows for a comprehensive understanding of how different disciplines, such as environmental design, cognitive psychology, and crowd science, address navigation in emergency contexts (Bi & Gelenbe, 2019; Farr et al., 2012; Chou & Cho, 2023). Rather than focusing on a single variable, the review aims to integrate multiple perspectives to build a more holistic understanding of wayfinding (Lin et al., 2020; Lin et al., 2023; Duan, 2024).

1. Scope of Review
The review focuses on three main domains:

- Wayfinding and spatial navigation
- Human perception and behavior in emergencies
- Crowd management and evacuation systems

Sources include peer-reviewed journal articles, conference proceedings, and foundational theoretical works.

2. Analytical Strategy
The selected literature is analyzed using a thematic synthesis approach, where key findings are grouped into recurring categories. This process enables the identification of patterns across studies and highlights relationships between spatial design, human behavior, and management systems. Through this synthesis, the study develops a structured understanding of the key dimensions influencing wayfinding in evacuation contexts.

RESULT AND DISCUSSION

1. Key Dimensions of Wayfinding in Evacuation
The analysis of the literature reveals that wayfinding in evacuation contexts can be understood through three interconnected dimensions: spatial and technical factors, human perceptual and behavioral factors, and organizational and management factors. These dimensions provide a structured framework for examining how individuals navigate complex environments, particularly under emergency conditions. Rather than operating independently, they interact dynamically, shaping both individual decision-making and collective

movement. By organizing the discussion into these categories, this section aims to clarify the key components that influence wayfinding performance and to establish a foundation for a more integrated understanding of evacuation processes in high-density environments such as stadiums.

a. Spatial and Technical Factors

Spatial and technical factors constitute the fundamental components of wayfinding systems, as they shape how information is visually presented and spatially organized within an environment. Effective wayfinding relies on principles of visual communication to ensure that users can quickly perceive, interpret, and respond to spatial information, particularly in high-pressure situations such as emergency evacuation.

1) Spatial Legibility

Spatial legibility refers to the clarity of environmental structure that enables users to understand and navigate space effectively (Kaplan & Kaplan, 1982; Weisman, 1981). Environments with clear layouts, logical circulation paths, and coherent spatial organization allow users to form cognitive maps more easily, supporting efficient navigation. In complex environments such as stadiums, high spatial legibility reduces disorientation and minimizes the cognitive effort required to interpret space. This becomes especially important in emergency situations, where individuals must quickly identify routes and make decisions under time pressure.

2)Visibility and Signage

Visibility is a critical factor in emergency conditions, where users must quickly identify exits and safe routes. Effective signage systems are characterized by clarity, strong contrast, and strategic placement at key decision points (Arthur & Passini, 1992; Calori & Vanden-Eynden, 2015). In addition, consistency in design such as color coding, symbols, and typography that supports faster recognition and comprehension. Poor visibility and inconsistent signage are frequently associated with navigation errors, hesitation, and delays in movement (Li et al., 2021). In high-density environments, these issues can escalate into congestion and reduce overall evacuation efficiency.

3) Landmarks and Environmental Cues

Landmarks serve as key reference points in navigation, helping users orient themselves and make directional decisions. Environments with clear and distinctive landmarks enhance spatial awareness and support route selection (Parush & Berman, 2004). Landmarks can include architectural features, visual markers, or unique spatial elements that are easily recognizable. However, in emergency contexts, their effectiveness depends on visibility, distinctiveness, and relevance to the evacuation route. If landmarks are obscured, poorly positioned, or not clearly associated with navigation paths, their ability to support wayfinding becomes limited.

b. Human Perception and Behavioral Factors

1) Decision-Making Under Stress

An emergency situations, decision-making is strongly influenced by stress, urgency, and limited cognitive capacity (Haghani & Sarvi, 2019). Under such conditions, individuals are less able to process complex information and are more likely to rely on simple, intuitive judgments. This often leads to heuristic-based decision-making rather than rational evaluation of all available options. As a result, the design of wayfinding systems must consider how information is perceived quickly and intuitively, rather than assuming users will carefully analyze their surroundings.

2) Behavioral Patterns

Common behaviors during evacuation include following the crowd, choosing familiar routes, and hesitation at decision points (Shi et al., 2021; Hochmair et al., 2008). These patterns reflect the influence of social behavior and prior experience on navigation decisions. While following others may provide a sense of safety, it can also lead to uneven distribution of movement and congestion in certain areas. Similarly, reliance on familiar routes may prevent individuals from using alternative exits that are more efficient. These behaviors highlight the importance of designing systems that can guide both individual and collective movement effectively.

3) Wayfinding Entropy

Wayfinding entropy arises when individuals encounter multiple choices or conflicting information,

leading to uncertainty and reduced navigation efficiency (Hirsh et al., 2012). In such situations, users may hesitate, make incorrect decisions, or repeatedly change direction. High wayfinding entropy is often associated with poorly organized environments, unclear signage, or inconsistent information. Reducing this uncertainty is essential for improving evacuation performance, particularly in high-pressure scenarios where time and clarity are critical.

c. Organizational and Management Factors

1) Crowd Management

Crowd management focuses on proactive planning strategies aimed at organizing and guiding the movement of people. This includes spatial planning, circulation design, and the implementation of information systems that support navigation (Fruin, 1993; Still, 2013). Effective crowd management seeks to prevent congestion, distribute movement evenly, and ensure that evacuation routes function as intended. It plays a key role in supporting the effectiveness of spatial and wayfinding systems.

2) Crowd Control

Crowd control involves reactive strategies implemented during emergency situations, such as restricting movement, redirecting flows, or managing access to certain areas (Fruin, 1993). These measures are typically used when normal movement patterns become unsafe or when unexpected conditions arise. While necessary, crowd control is most effective when supported by prior planning and clear communication systems.

3) Risks of Poor Management

Failures in crowd management can result in serious consequences, including crowd crushes, panic behavior, and infrastructure-related incidents (Kingshott, 2014; Rahmat et al., 2011; Berlonghi, 1995). These risks are often exacerbated by poor coordination, lack of information, and inadequate spatial design. In high-density environments such as stadiums, ineffective management can significantly increase the likelihood of accidents and reduce the overall safety of evacuation processes.

d. Discussion

1) Fragmentation in Existing Research

The review reveals that much of the existing literature examines wayfinding through isolated variables, such as signage design, spatial layout, or crowd behavior, without adequately addressing their interdependencies. For example, studies on signage often focus on visibility and readability (Arthur & Passini, 1992; Calori & Vanden-Eynden, 2015), while research on crowd behavior emphasizes movement patterns and social influence (Shi et al., 2021; Hochmair et al., 2008). Similarly, spatial studies highlight the role of legibility and environmental structure in navigation (Kaplan & Kaplan, 1982; Weisman, 1981).

However, as discussed in the previous sections, evacuation performance is not determined by any single factor. The effectiveness of signage depends on how quickly it can be perceived under stress, the usefulness of spatial layout depends on how individuals interpret it in urgent situations, and crowd movement often overrides planned navigation routes. In emergency contexts, where users rely on rapid perception and heuristic decision-making (Haghani & Sarvi, 2019), these elements interact dynamically rather than independently.

This fragmentation limits the applicability of existing findings in real-world stadium evacuation scenarios. Design solutions based on a single perspective such as improving signage without considering crowd flow may fail to produce meaningful improvements in evacuation efficiency. Therefore, a more integrated approach is required to understand how wayfinding operates under complex and high-pressure conditions.

2) Toward an Integrated Framework

Based on the synthesis of the literature, wayfinding in evacuation should be understood as an interaction between spatial, perceptual, and management systems. These dimensions are interconnected and must be addressed simultaneously to improve evacuation performance.

First, spatial systems, this including layout, visibility, and signage. Provide the physical and visual structure that supports navigation. As highlighted earlier, environments with high legibility and clear visual cues enable faster route recognition and reduce cognitive load (Kaplan & Kaplan, 1982; Arthur & Passini, 1992).

Second, perceptual systems relate to how individuals process information and make decisions under stress. In emergency situations, users rely on rapid perception, follow familiar routes, and often imitate the behavior of others (Haghani & Sarvi, 2019; Shi et al., 2021). This means that even well-designed spatial systems may not function as intended if they do not account for human behavior.

Third, management systems involve planning, coordination, and control of crowd movement. Effective crowd management ensures that spatial design and wayfinding systems are supported by appropriate strategies, such as directing flows and minimizing congestion (Fruin, 1993; Still, 2013).

The integration of these three systems reflects an interdisciplinary perspective that connects environmental design and crowd science. Rather than treating wayfinding as a purely visual or architectural problem, this approach positions it as a socio-spatial system, where space, perception, and management interact to shape evacuation outcomes.

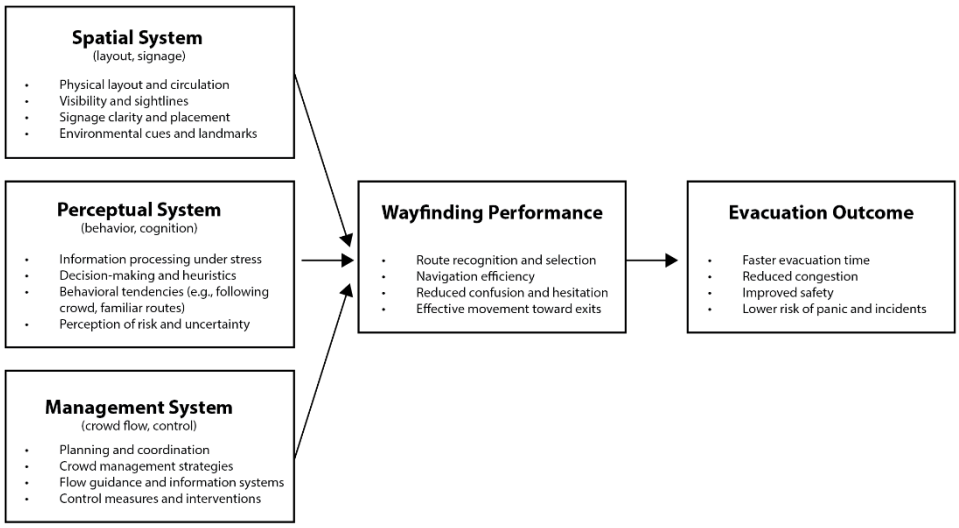

Figure 1. Framework base on literature
(*Source: Muhammad Tafakur,*2026)

3) Implications for Stadium Design

The findings of this review show that wayfinding systems in emergency situations should prioritize rapid perception rather than detailed interpretation. In normal conditions, people may take time to read and understand information. However, during emergencies, stress and urgency reduce their ability to process complex information (Haghani & Sarvi, 2019). As a result, wayfinding elements need to be immediately understandable. Clear signage, strong contrast, simple symbols, and direct visual cues are more effective than text-heavy instructions (Arthur & Passini, 1992; Calori & Vanden-Eynden, 2015). This supports the idea of spatial legibility, where environments that are easy to understand at a glance help users navigate more efficiently (Kaplan & Kaplan, 1982; Weisman, 1981).

In addition, signage must be designed in relation to crowd movement patterns. During evacuation, people often follow others instead of making independent decisions, which can lead to crowd concentration in certain areas (Shi et al., 2021; Hochmair et al., 2008). If signage directs people in ways that do not match the natural flow of the crowd, it may be ignored or cause confusion. This situation can increase uncertainty, or what is referred to as wayfinding entropy (Hirsh et al., 2012). Therefore, signage systems should support and guide existing movement patterns rather than contradict them (Fruin, 1993; Still, 2013)Finally, evacuation systems need to consider human behavior under stress. People do not always act rationally in emergency situations. They tend to choose familiar routes or follow others, even if these are not the fastest options (Haghani & Sarvi, 2019). Stress and fear can also cause hesitation and poor decision-making. Because of this, wayfinding design should not rely on users making optimal choices. Instead, it should guide behavior through clear visual cues, visible exits, and simple spatial organization (Parush & Berman, 2004; Li et al., 2021).

CONCLUSION

This study has examined wayfinding in emergency evacuation through a structured review of literature across spatial design, human perception, and crowd management. The findings demonstrate that evacuation performance in complex environments such as stadiums is not determined by a single factor, but by the interaction between spatial and technical systems, human behavioral responses, and organizational strategies. The review highlights that spatial clarity, effective signage, and the presence of recognizable environmental cues are essential in supporting navigation. However, their effectiveness is closely dependent on how individuals perceive and respond to these elements under conditions of stress and urgency. In emergency situations, users rely on rapid perception and simplified decision-making processes, often influenced by social behavior such as following the crowd or choosing familiar routes. At the same time, the role of crowd management is critical in shaping and regulating movement, ensuring that spatial and perceptual systems function effectively within real-world conditions.

A key contribution of this study is the identification of fragmentation in existing research, where spatial, behavioral, and managerial aspects are often addressed separately. To address this limitation, the study proposes an integrated perspective that conceptualizes wayfinding as a socio-spatial system, where environment, perception, and management interact dynamically. This perspective provides a more comprehensive understanding of evacuation processes and highlights the importance of aligning design, behavior, and operational strategies. In practical terms, the findings suggest that wayfinding systems should prioritize immediate visual comprehension, align with natural crowd movement patterns, and account for human behavior under stress. For stadium environments, this implies the need for coordinated design approaches that integrate spatial layout, visual communication, and crowd management planning.

This study is limited by its reliance on literature synthesis and does not include empirical validation. Future research is recommended to explore this framework through experimental studies, behavioral observation, and simulation-based analysis. Such approaches would provide deeper insight into real-time evacuation dynamics and support the development of more effective wayfinding systems in high-density environments.

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