2025 NOCoE Transportation Technology Tournament

Real-Time Pedestrian Traffic And Crowd Management Using Fiber-Optic Sensing Systems

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1. Overview

1.1 Problem Statement

The 2026 FIFA World Cup is a national soccer tournament that will have 63 matches played across 11 stadiums in the United States from June to July of 2026. The matches will bring hundreds of thousands of fans from all across the globe, which means an influx of vehicle and pedestrian traffic in effected areas.

The capacity for all 11 stadiums is a combined 690,000 people. Which doesn't account for the fan pop-ups and watch- parties outside of the stadiums. Huge events such as the FIFA World Cup can cause major traffic delays on the roads, but they can also cause delays in entering, navigating, and exiting the stadiums. While this is an inconvenience for the fans trying to watch the games, it can also be detrimental to someone having a medical emergency inside of the stadium.

Additional pedestrian traffic from major events hosted in stadiums poses a risk to safety and creates mobility challenges around these venues several times a year.

1.2 Study Area

For our solution, we will be focusing on the FedEx Forum in Memphis, Tennessee as our study area; however, we aim to have our solution be usable in any type of stadium or arena. The FedEx forum consists of three tiers of seating along with the court level floor. The target areas are the outside entrance on Third Street, and the plaza level concourse, as indicated by the green areas in Figure 1.

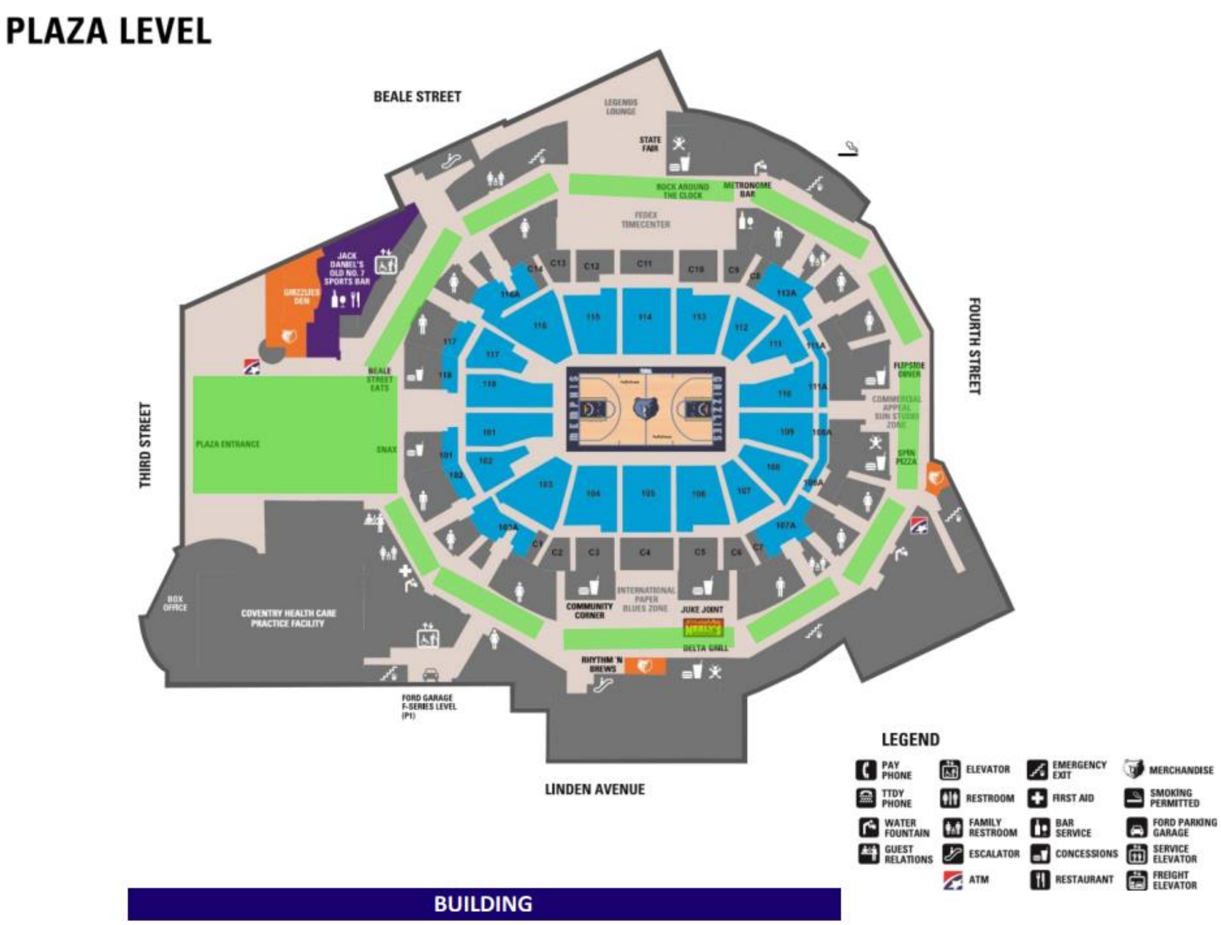

Figure 1. Plaza Level Map With Study Area

The FedEx Forum has a single grand entrance that takes visitors from the street level of Third Street and Linden Avenue and places them into the plaza level concourse, which has ticketing, restrooms, first aid, and many concession stands. This means that every single occupant for events will be entering and exiting out of the same area, which can cause queueing and delays and poses a safety and health risk to occupants.

1.3 Stakeholders

There are four main stakeholders for our team's solution:

- **General Public:** The tourists and fans attending events at the FedEx Forum can feel safter and less stressed.
- **City Planners and DOT's:** Real-time data can improve future operations.
- **Event Organizers**: The owners and the personnel that FedEx Forum hire for events that will have reduced liability and better crowd control.
- **Emergency Responders:** The Emergency Medical Technicians (EMT's) that might be called in for a medical event who can respond faster.

2. Solution Statement

This section aims to display our solution to overcrowding at the FedEx Forum. The approach consists of four different technologies: VisSim, Fiber-Optic Sensing (FOS) systems, portable changeable message signs (PCMS), and automatic gate arms, as shown in Figure 2.

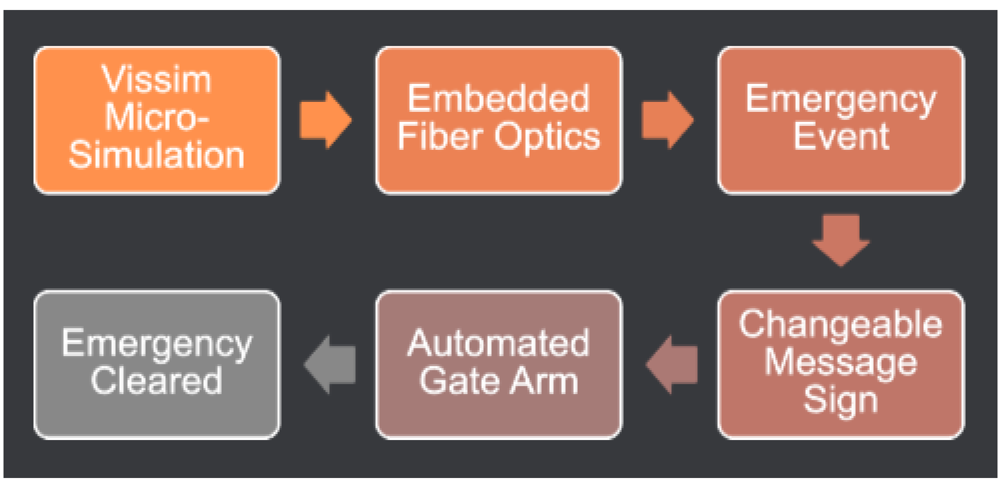

Figure 2. Design Flow

2.1 Solution Components

2.1.1 VisSim Micro-Simulation

VisSim is a virtual simulator that is currently primarily used to predict how drivers will behave on differently designed roads. The user inputs their criteria for the roads and is able to gather data based on virtually simulated drivers. In a case study by Inhi Kim et al. in 2013, they used VisSim in a way to predict how pedestrians would behave at a movie theater with different numbers of ticket booths. Using video footage of a movie theater, the researchers predicted how they thought the pedestrians would react and then used VisSim to confirm their predictions.

The first part of our solution approach depends on using a similar idea of predicting how occupants would enter and then navigate through the plaza concourse in the FedEx Forum. This is done by taking previous footage of a similar-sized event and collecting data to calibrate the VisSim program. This calibration will only need to be done the first few times our solution is used. The goal is to have the data from an event with 10,000 fans, 20,000 fans, etc. and the arena would be able to tell us the size of the event, and previous footage from different arenas will be applied. Using this data, the baseline for the expected behavior on the walkway for an event is known.

2.1.2 Fiber-Optic Sensing System

Fiber-Optic Sensing (FOS) systems have been used for real-time monitoring of crowd management and structural integrity. FOS systems, when used structurally in bridges and buildings, can detect strain, temperature changes, and vibrations. In a 2012 study, Bruno Costa and Joaquim Figueiras placed fiber optic cables on a steel bridge so that data on the structural integrity of the bridge could be monitored. They used the fiber optic cables as a strain gauge and as a means to measure the horizontal displacement of the bridge (Costa). This data is collected and used to calculate the structural integrity of the building.

The second part of our solution would be implementing a similar method of using fiber optics as a strain gauge. Instead of constructing a building around fiber optics, we want to create a way for the fiber-optic sensing system to be transportable to fit any size stadium. As shown in Figure 3. fiber optics will be embedded in a raised plastic walkway that has joint connectors at both ends. The sections of the walkway will be pieced together at the connection joints, with spaces in between certain areas, such as entrances to the bathrooms and to the stairs for seating. The pathways will have two going clockwise and two going counterclockwise around the plaza concourse.

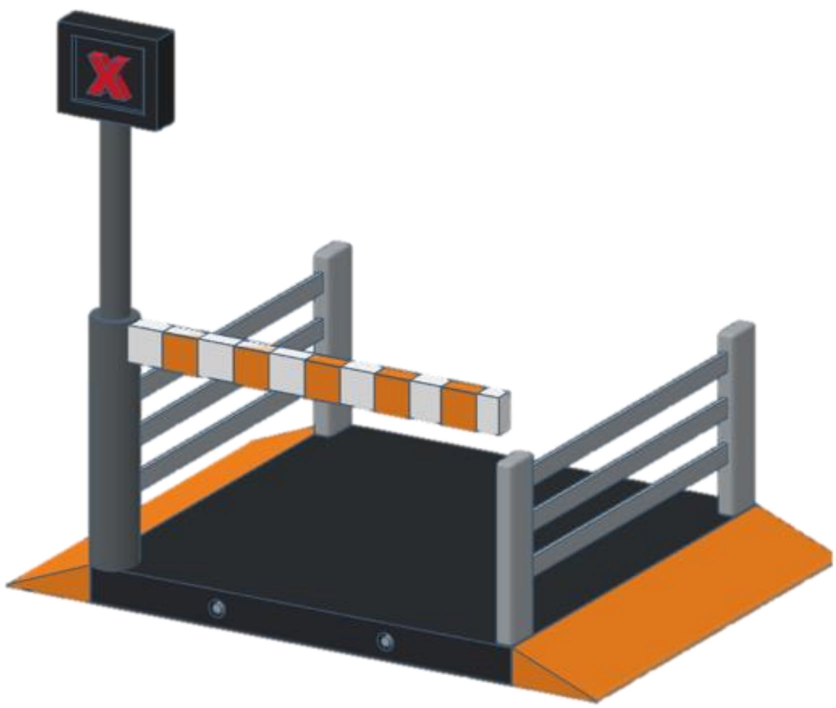

Figure 3. Portable Walkway Design

The data from the strain gauge would be matched up against the baseline data from VisSim, and when an unexpectedly high amount of strain is observed, it can be deduced that some sort of event is occurring in that area, whether it is medical or simply congestion from high traffic.

2.1.3 Portable Changeable Message Signs

The last part of our solution relies on portable changeable message signs with gate arms attached to them. These signs are normally used when roadwork is present or as incident management on interstates and highways. LED lights are able to be manipulated to display messages to drivers in order to decrease the chances of crashes or injury. Gate arms with flashing lights are used at railroad crossings to warn drivers and prohibit crossing when a train is near. For our system, the data from the FOS system will be interpreted, and when high levels of strain occur, the PCMS will receive a signal to change the message on the sign to show that that lane of the pathway is closed, and once emergency personnel arrive, the gate will lower until the cause of the strain has been removed. If the situation is not for medical reasons, the gate will still lower to reduce the queue in that line until the abnormal strain is removed. Figure 3. also shows the design of the PCMS with the gate arm, and how it will attach to the fiber optic walkway.

2.2 System Architecture

Several factors must be taken into account for our solution, including both the functional and physical needs of our product. The following sections go into detail as to what these needs are, and how they will be met.

2.2.1 High-Level Functional Architecture

There are four main components to the function of our proposed solution, each with its own parts. The first component is the VisSim simulation, which functions as a software that sets the baseline of the intended movements over the pathway. VisSim uses artificial intelligence to predict where it thinks a certain amount of people should go. The information is then transferred through a network to store that information. The next component is the portable walkway embedded with fiber optic cables. The cables' function is to provide real-time information on the density and speed at which people walk over the pathway. The information then gets uploaded into the network to store the information. The third component is the portable changeable message sign. The function of the sign is to show consumers if the path they are trying to take is currently available. The last component is the automatic gate arm, which functions as a physical barrier to consumers if they still try to enter a closed off pathway after the changeable message sign has changed.

2.2.2 High Level Physical Architecture

The high level physical architecture of our proposed solution requires several parts. With regards to the VisSim simulation, previously recorded videos from the arena is required, along with a computer to load the information gathered from the video onto VisSim. There will also need to be a host computer located at the arena where the information from VisSim and the fiber optics in the walkway can be sent to. The physical needs for the fiber optic embedded walkway includes the fiber optic cables and the plastic walkway encasing the cables. The PCMS is also required for the walkway, and for its own purpose. The PCMS will require LED lights and python code that can be changed from the host computer when the VisSim and walkway information indicate an emergency. The physical requirements for the automatic gate arm is the gate arm itself, which is made from plastic. The gate arm also requires python code that would lower or raise the arm when the PCMS changes from an X to a check mark, respectively.

3. Anticipated Impacts

This section aims to display how our solution approach has the potential to positively impact a wide range of people and other areas that are affected by overcrowding.

3.1 Benefits

3.1.1 Operational Benefits

The first impact that we anticipate is from an operational standpoint. VisSim, Fiber-Optic Sensing systems, and portable changeable message signs, can eliminate the need for manual crowd direction due to the real-time responsiveness produced by each of these systems. Additionally, this system can be flexibly deployed across different venues, event types, or other cities. The versatility that our system offers is crucial because it allows other entities to utilize this system to mitigate overcrowding and slow emergency response times.

3.1.2 Safety Benefits

We also expect our system to produce positive impacts on health and safety, contributing to safter environments for pedestrians and emergency response teams. Our real-time adaptive technology and symbol-based signage prevents dangerous crowd build-up and stampede risks through early detection and automatic rerouting. As a result, pedestrians will experience reduced physical strain and anxiety because of a decrease in overcrowding and long wait times. Therefore, drastically impacting emergency response access, which will help pedestrians receive the medical attention they need in a timely manner.

3.1.3 Other Benefits

Lastly, our system heavily contributes to an environmentally friendly solution approach and helps the pedestrians feel more comfortable in highly stressed situations due to overcrowding. From an environmental standpoint, our technology offers a low energy digital solution, which will save on costs and resources. Our technology will also help pedestrians feel less confused when navigating the stadium. The fiber optic sensing system will influence pedestrians to follow specific paths making transportation inside the stadium more organized. As crowd movement becomes more organized, legal and insurance risks tied to injuries, delays, or overcrowding are mitigated.

3.2 Potential Challenges

A potential key challenge of this innovation is the integration of fiber-optic sensing hardware with temporary infrastructure, which may complicate calibration. Ensuring reliable, wireless communication between sensors and the digital display signs could also face interference in heavily crowded atmospheres. Another concern is that the system's effectiveness depends heavily on accurate simulation, which may not capture real-world unpredictability.

4. Conclusion

The proposed innovation combines micro-simulation, fiber-optic sensing, and digital display message signs to create a responsive, adaptable system for managing pedestrian flow, scalable to any size event. By proactively responding to overcrowded environments, this system promotes both operational efficiency and public safety. Although potential issues such as system calibration must be addressed, the potential benefits far outweigh these challenges. Ultimately, this approach offers a scalable, innovative framework that can be applied across various event settings and sizes to better control crowd management and emergency response access.

5. Acknowledgements

Our team would like to extend our sincere gratitude to Dr. Ivey and Dr. Robinson for their support throughout this project. Their feedback on presentations and their helpful tips on effectively communicating complex ideas played a crucial role in shaping our work. They worked relentlessly to acquire as many guest speakers as possible to share their career experiences and provide guidance that helped broaden our understanding of the transportation and technology field. We are also grateful to our mentor, Pete Schlesinger, Intelligent Transportation Systems Program Manager for the City of Memphis, whose insights into local transportation infrastructure and ITS solutions were invaluable. Finally, we greatly appreciate the U.S. Department of Transportation, NOCoE, and the organizers of the Transportation Technology Tournament for creating this opportunity to engage with real-world transportation challenges and connect with professionals in the field.

7. References

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