Analyzing Response Communication Mitigation Methods through Simulation Modeling

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Abstract

Emergencies rely heavily on succinct and controlled announcements from a singular verified source. However, this has been an ideal as opposed to reality. Often, veritable communication has occurred after events, as official sources may not have been available to comment or provide personal instruction to individuals. Current communication simulation modeling shows communication systems that do not mirror actual communication. Systems are not the only way information spreads. This study analyzed formal and informal response communication methods in an emergency at a large event venue. By comparing multiple methods in a systems dynamic model, the researchers estimated the relative value of four different communication sources regarding impact and response metrics. Additionally, these numbers have influenced future agent-based models that reflected a real evacuation in communication messaging.

The study resulted in increased understanding of evacuation communication procedures as well as the testing of multiple forms of communication at one time. The models offered additional proof that the most reliable and rapid communication offers the most impact to saving lives. Additionally, these procedures gave insight into communication effectiveness as well as the best combinations of messaging. Thus, the models, as estimates, should offer insight into the current communication response procedures and their future applications.

Introduction

Current communication simulation modeling focuses on network systems as opposed to a public response to the systems themselves. Though network systems are still vital to the

notification process during an emergency, they are not the main way of relaying urgent information to the public at risk. Thus, focusing on newer technology has led to a gap in evaluating communication mitigation methods. These analog systems are still being used in emergencies and should be evaluated for optimization, effectiveness, and usability. Additionally, the evaluation of these systems does not focus on the physical time involved in the message process. Time is a piece of quantitative data that directly relates to potential lives saved. Consequently, the faster a message is communicated and understood, the sooner a person can evacuate. **Another measurable piece of quantitative data is the number of people that receive that message. These two data points**

Additionally, communication structures often involve more than one communication system. For example, an Amber alert and a tornado siren have a similar communication structure but differ in how many messages they send. Both relay a message to a receiver, but the delay and number of messages are much larger for the Amber Alert, which use multiple communication systems to relay one message to many types of people multiple times. It is considered more effective than broadcasting a single message many times on one device. Spreading messages this way ensures that a single person has a greater likelihood of seeing and understanding the message when it comes from multiple channels. In a 1990 study, communication structure, public response to an emergency message falls into a six-part process: hearing, understanding, believing, personalizing, deciding and responding, and confirming Mileti & Sorensen, 1990).

In an emergency, false and inconsistent messages occur. For Homeland Security, emergencies rely heavily on succinct and controlled announcements from a singular verified source. However, this is an ideal as opposed to the reality (DHS, 2014). Communication will often be announced after the event; official sources may not be available to comment immediately or provide personal instruction to individuals. Worse, the communication itself will stem from various sources that may worsen the emergency. An example of multiple sources would be the difference between formal and informal sources.

When modeling active shooter scenarios, communicating proper procedure essentially saves lives. Notifying authorities increases response time, which prevents fatalities. The shooter will engage the police instead. In the 2015 Orlando nightclub shooting, police were notified at 2:02 a.m. from an off-duty officer acting as a security guard (Ellis, Fantz, Karimi, & McLoughlin, 2016). This was four minutes after shooting started. However, additional external communication did not only come from the Orlando Police Department. Rather, the nightclub itself used social media to communicate with patrons. People inside also provided personal and external communication to the police or family members.

Active shooters represent a scenario in which communication and procedure must be set in place prior to the emergency to accurately work. In this way, simulation modeling can provide “practice” in distribution of responders, areas of weakness, and effective communication. Choosing a simulation modeling source means selecting a system that provides multiple modeling scenarios. AnyLogic Personal Learning Edition offers a limited

but diverse model creation. Using agent-based logic, modeling communication could be as realistic and individualized as needed.

Venue Case Studies

Venues must adapt to different daily scenarios as crowds change with the event. Therefore, getting an accurate evacuation time is difficult, mostly because publishing these data has the potential to hurt a venue's security. Based on evacuation times in apartment buildings, the average time to start evacuating (from a fire) is approximately 10 minutes, assuming alert systems are in place (Proulx, 1995). In combination with that time, the average evacuation took approximately 22 minutes to complete. However, this study was done on apartment buildings as opposed to a large event venue like a stadium. Given the magnitude of such, evacuation times are more akin to typical exit procedures. However, these times are not measured and may be skewed, as patrons are not forced to leave. Therefore, the Proulx study may be more useful to compare timing than data collected from an after-hour's event. This study also considered mobility constraints involving those with special needs. Ultimately, the study shows that the communication affects evacuation rates. The next step was to compare this information to large event venues and their communication methods.

In a 2014 study of Ladd Pebbles Stadium in Mobile, Alabama, focusing on stadium design, researchers speak to the international standard of 8 minutes for a stadium evacuation to occur. This study focuses on the physical limitations associated with evacuations (crowding, collisions, social norms, etc.). However, they speak little of communication factors that could affect timing in an emergency. Instead, this study focuses on evacuation flow rate simulation, avoiding and assuming communication dynamics (Aldana, Fox, Diehl, & Dimitoglou, 2014). However, case studies show how vital communication is to evacuation planning. At AT&T Stadium, staff members are given a rundown on their tasks of the day and safety expectations at the beginning of each shift. These task sheets include updates and reminders for the event and provide photos of what the passes and wristbands look like, so there are no copies (AT&T, 2018). It also reminds them if they see something, to say something. Each staff member is also expected to get a formal safety briefing from his/her supervisor prior to doors opening.

However, arenas are not the only example of a large event venue. University stadiums, arenas, and event centers are typically less secure but at higher risk for an emergency. Surveying three universities and their plans offered a more comprehensive list of evacuation procedures and methods. Additionally, these case studies offered the opportunity to see how they communicated information consistently to both long-time and first-time visitors. Though they also showed methods related to staffing, this was less important to the research now. Townson University has a public version of its arena's emergency response plan, and it outlines a list of important information for event staff to know before an event. This list covers familiarizing staff and contractors on emergency procedures, fire procedures, emergency exit policies, equipment and seating policies, and other general rules. The Townson report explains all the procedures during an emergency. As soon an incident occurs, it is noted on the PA and a bullhorn in case of a fire alarm or PA equipment failure;

the TUPD will designate a safe location outside; management will direct patrons in evacuating and will use the radio to communication, and an operations commander will be assigned. These procedures are based on the National Incident Management System, the National Response Framework, and the Incident Command System. These provide guidelines for "preparedness" and compliance. Anyone involved in security management should be fully aware especially when ensuring the safety of more than several hundred people (Towson, 2018).

From the above case studies, response requires necessary preparation and practice. Based on this information, evacuation times should be estimated at approximately 20 minutes for an average venue with systems in place prior to the event itself. This time includes both the processing and actual physical evacuation time. The communication methods employed by these venues are further explored in the following section.

Emergency Communication Methods

In 2008, the Department of Homeland Security designed a planning guide for emergencies in stadiums. The guide has a section for a notification system during emergencies. During emergencies, understanding the different reactions that people can have is important to consider, and different possibilities can be used to help design an efficient notification system. The employees also need to be trained and informed on all aspects of the system to be sure the communication will be effective. Using common language during emergencies allows everyone to understand any given information. The guide also advises the necessity of having a plan where information can be displayed (screens, jumbotrons, etc.), along with ensuring that employees check areas without any displays (DHS, 2008), thus exploring communication response methods related to two communication systems: visual and audio. Sight and hearing are the primary ways that any person will begin to understand a message.

Stadiums typically have public announcement systems that will take into consideration both visual and auditory public announcement system but do not capitalize on additional communication systems that may be available to their audience. As an example, Banker's Life Fieldhouse uses video announcement and public announcement systems to address the public (Bankers, 2018). According to Kenneth Burke, the percentage rate of text messages being opened is 99%. Burke's article also states that 95% of text messages are opened within three minutes and, on average, read in less than five seconds (2016). This statistic is particularly useful, considering that many stadiums have fan text messaging that could evolve into an emergency communication service. For example, Bankers Life Fieldhouse, a stadium in Indianapolis, Indiana, offers several different fan information services. Among website information is the fan texting service. Bankers Life Fieldhouse offers a texting service that fans can use if they ever encounter anything suspicious during events. The service is anonymous so they can inform building management without giving personal information. Bankers Life Fieldhouse also specifies that if the service is misused, the number will be blocked for a full 24 hours (2018).

According to *Cutlip and Center's Effective Public Relations* (2013), there are several communication methods to apply to audiences (Broom, Sha, Seshadrinathan, Center, & Cutlip, 2013). Among the various communication models (and relevant to communications in emergency management), "the mass communication model is the most effective. The mass communications model has 6 elements: 1) the sender, 2) the message, 3) the medium or channel, 4) the receivers, 5) relationship contexts, and 6) the social environment." Therefore, the sender is the source of the impact and can influence how it is received (Broom et al., 2013). Consequently, credibility intensifies information and could impact how effectively a message. A message is information that is sent or given to someone.

Furthermore, from Cutlip and Center, messages are categorized into "text, verbal, multimedia, print, etc." (Broom et al., 2013). Assumption suggests that emergency management messages have to be clear and concise. However, interpretation occurs when communicating with the masses and must be considered as a potential obstacle when crafting a message (Broom et al., 2013). The medium or channel that a message uses has an equal importance to the message. From a 1971 body language study, face-to-face communication delivers effective communication information, yet 70- 90% of communication involves nonverbal cues, such as gestures and facial expressions (Mehrabian, 1971). Direct communication, like body language, is valuable, but using technology, such as social media, as a medium for communication has resulted in creating more ways to communicate during emergencies (Broom et al., 2013). These options should be explored more fully in terms of emergency communication.

Alertus Technologies is a unified mass notification communication system. Alertus is often used for large events and companies for emergency situations. Alertus utilizes a combination of communication methods to maximize the possibility of reaching all parties. Different methods include texting message, email, public announcement systems, digital signage, desktop computers, etc. A few companies that utilize Alertus Technologies include Disney, ESPN, and Toronto Pan AM Sports Centre (Alertus Technologies, 2018). This technology system appears to encompass all communication systems in a mass effect. However, the full system relies on the combination of systems. Whether this combination is effective or not depends on how accurate or effective the communication is. Alertus does what many arenas are capable of but in a way that puts the control in a unified separate entity.

Methods

In developing a way to model response communication, the researchers determined that a system dynamics model would provide a new look at response communication. Response communication requires speed, time, and people. Balancing these three variables is essential to effective communication. These variables can influence some constants, such as communication and evacuation rate. Thus, communication is a system that can be made more effective and accurate through modeling. The systems dynamics model being used is based on a Bass diffusion model. Developed in 1969 by Frank M. Bass and John A. Norton, a Bass diffusion model represents a how a potential market is affected by advertisers and word of mouth (1987). Advertising has the potential to spread a concise, clear, and strong message

with little to no resources. Thus, this model is a helpful reference for emergency communication.

Regarding this specific project, the Bass diffusion model has been changed to reflect emergency communication. This method was chosen based on how well advertisement mirrors communication. It necessitates and requires effective understanding but also showcases errors that are corrected based on an alternate system. Bass diffusion takes communication by word of mouth into consideration and is a large part of emergency communication. If all emergency communication systems were to fail, word of mouth would still be prevalent. Thus, word of mouth acts as a constant in our model of emergency response communication. However, it has an obvious error rate regarding miscommunication and timely understanding.

Bass Diffusion Model

As seen in Figure 1, initial method research was conducted to see how well a Bass diffusion model could adapt to emergency communication. By replacing the population to reflect the emergency at hand, the communication rate is no longer influenced by advertisement but an auditory public announcement (PA) system. As mentioned, word of mouth communication is still reflected and influenced by contact rate and the evacuation message rate (Norton & Bass, 1987). The model appeared to accurately reflect evacuation message procedures, including a delay that reflects understanding or processing time.

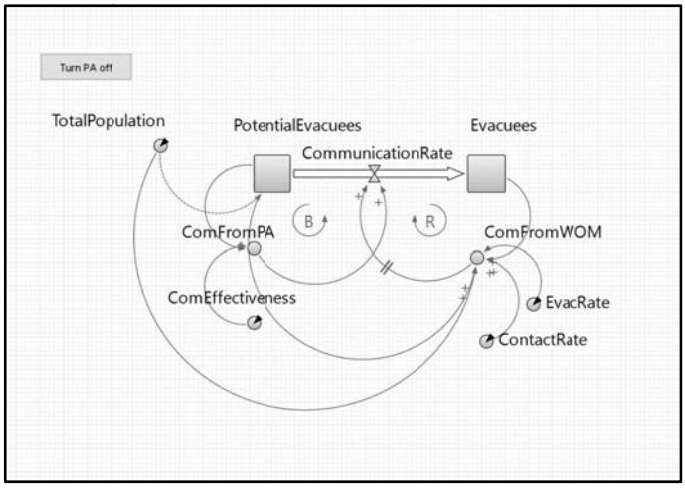

Figure 1. Original Bass diffusion model.

Regarding this research, the error lies in uniformity of message. Different communication systems have different challenges. Because the message to evacuate goes through several different paths, some of the messages are delayed, whether this is through human or technological dictated circumstances. Developing a flowchart showed the specific challenges associated with each system and how they could apply to the model. As seen in Figure 2, steps associated with each system should result in understanding. This is where the Bass

diffusion model ends, as understanding implies that they have fully received the evacuation message. This does not account for the actual time that it would take for a person to evacuate, a lengthier process.

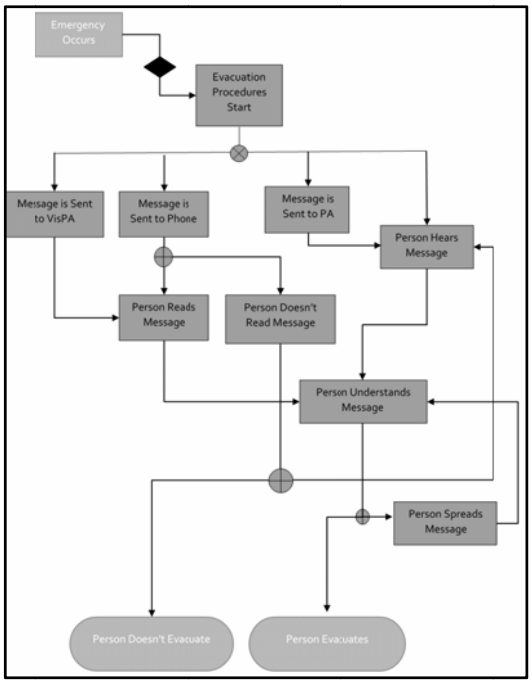

Figure 2. Communication flowchart.

The flowchart shows the four systems that could be modelled in an evacuation communication scenario. This is meant to come from the viewpoint of evacuees, not the first responders that would arrive. Therefore, the communication systems are all processes that the average person would have available. The four communication methods used were an auditory PA system, visual PA system, texting notification system, and word of mouth. These systems are shown in Figure 3.

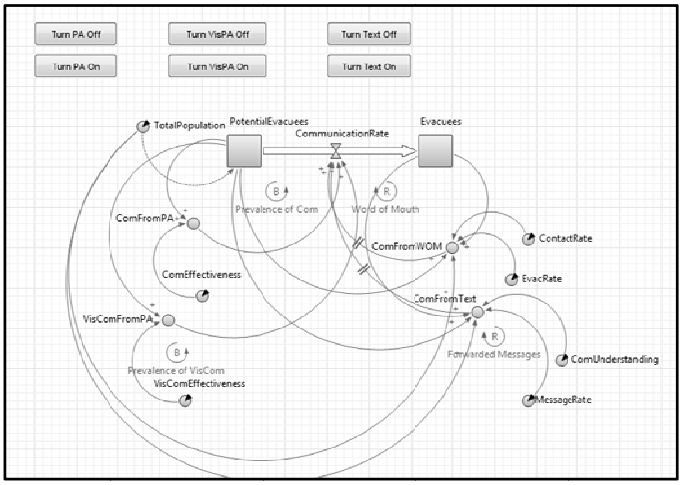

Figure 3. Final Bass Diffusion model.

For example, limited research suggests that public announcement systems are 60% effective at distributing a message (Alertus Technologies, 2018). This comes from public relations data as opposed to testing of several emergency public announcement systems. However, this assumes that the system is in perfect working order without any limitations (noise, miscommunication, etc.). Because the model is highly flexible, these circumstances can be reflected by inputting different numbers into the effectiveness variables. Using averages obtained from studies of similar systems, effectiveness was a variable inputted at different levels depending on which system was in use. Thus, effectiveness for both public announcement systems (auditory and visual) used the same initial effectiveness rating of 60%, while the texting system was given a 50% effectiveness rating but with a message rate of approximately 5% considering how often people would check their phones in each emergency. The five-second delay is implemented in the program as well. Text message systems align closely with word of mouth, as they are a technological reflection of the same process but with higher numbers.

Finally, word-of-mouth communication had a contact rate of approximately 1.1% as shown in prior Bass diffusion models. Word of mouth is a communication system that exists at all times. Visual and audible systems only boost this system, but it does require proximity to work. In the specific scenario, people are in proximity to the event and the message. However, word of mouth will act as a constant in this evacuation scenario. The effectiveness dictated by evacuation message rate set to 50%.

Pedestrian Traffic Model

Using an agent was necessary to show the second part of the flowchart in which the message is spread through behavior. The pedestrian model is essential to understanding how long it would take people to actually evacuate considering communication. This can be corroborated by drills and reported data in the future. People are the distributors of messages and their behavior should be considered. Stadium evacuation simulation has been used previously to measure crowd dynamics. In the study of Ladd Pebbles Stadium, the researchers compare crowd simulation models. The chosen model is behavioral, using agent-based modeling as a means of crowd simulation. This forms a more fully formed approach to stadium emergency evacuation and verifies that simulation can be used as a valid approach to evacuation research (Aldana et al., 2014).

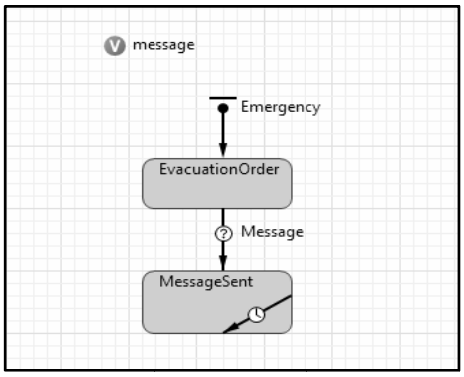

Figure 4. Pedestrian model statechart.

The physical structure of the pedestrian model is meant to reflect stadium seating so that communication rate is as close to realistic as possible. The model uses two waiting areas to simulate to arena sections that will fill with separate agents. The agents all begin as blue, until the evacuation order is released. Then the message is sent. Once one person has the message, s/he will turn red, depending on contact and proximity. Error is included to account for misunderstanding due to chaos and human error.

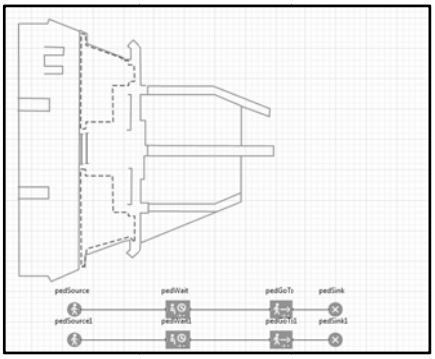

Figure 5. Final pedestrian model.

Ultimately, the final pedestrian model (Figure 5) simulates one necessary communication method. Additional methods will require further modelling to validate and continue testing. This is something the researchers hope to pursue in the future especially as new communication methods become popular.

Results

Using the results from the systems dynamics model, the researchers modelled the effectiveness of different communication systems. Using word of mouth as a constant, three communication methods can be compared against those initial values. Figures 6 and 7 show two lines. The darker line is the level of potential evacuees (the initial population) and the level of evacuees (the amount of people that successfully received the message). Acting as constant, word of mouth effectively distributed information in approximately 22 minutes. As

a reminder, this is not an evacuation time but the communication message time. As seen in Figure 6, the halfway point for the communication rate is much further than any other system.

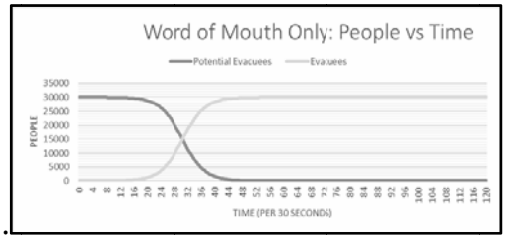

Figure 6. Word of mouth communication only.

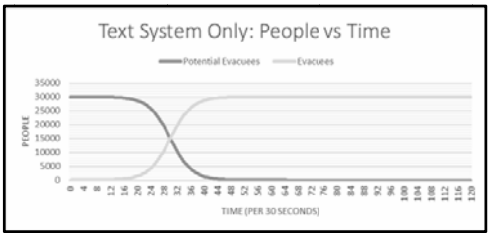

Figure 7. Text system only.

Comparatively, a text system in combination with word-of-mouth communication is only slightly better, taking approximately 20 minutes to spread an evacuation message. The system in question acted similarly if a single message was sent and spread among a stadium's fan service list. This would give a large event area the greatest chance at reaching patrons without using social media. It should be noted that this parameter requires further study to establish proper manipulation and realistic boundaries.

However, the systems that were more successful at issuing the message were the public announcement systems. The audible public announcement system took approximately 10 minutes to communicate an evacuation message. As previously noted, these conditions were almost ideal for the public announcement system but also assumed consistent communication being relayed at reasonable intervals (Figure 8). This system is necessary but also ignores some special populations.

The visual system was overwhelmingly the best at successfully displaying an evacuation message. The system took approximately 8 minutes to effectively communicate an evacuation message (Figure 9). This includes the timing and understanding delay incorporated into the data.

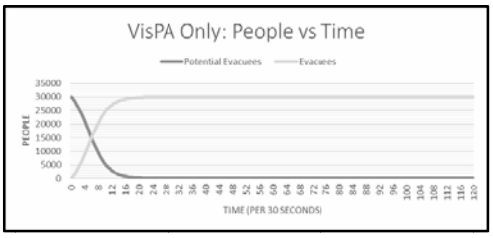

Figure 8. VisPA system only.

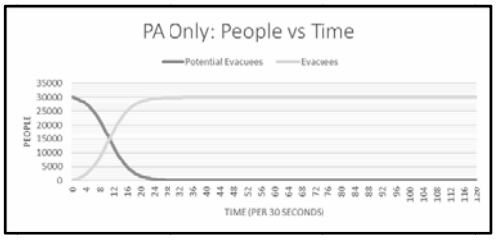

Figure 9. PA system only.

Additionally, we have included an example of all the combined communication methods (Figure 10). This model took approximately 9 minutes to complete, showing how multiple communication methods may negatively affect a message spread when factoring in additional error rates. The all-methods communication scenario also reflects an inundated communication in which a consistent error message breeds inaccuracies and response times.

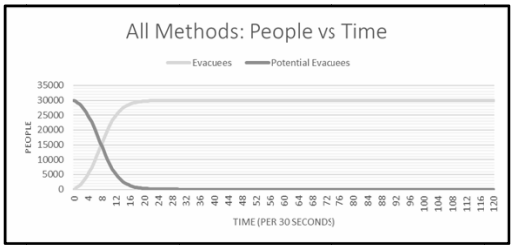

Figure 10. All communication methods.

Ultimately, the knowledge obtained from the resulting information will help improve and test emergency communication methods. This can be seen in the pedestrian model, as it models contact with the message more realistically than a systems model. The contact that the model has shown that contact rate does influence how quickly a message spreads and how word of mouth is the greatest influencer for that message. In this project, word-of-mouth communication can improve and introduce error into any communication system. Therefore, it is possibly the greatest asset or hindrance to response communication.

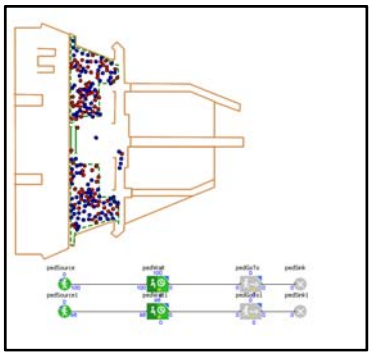

Figure 11. Pedestrian traffic model.

The pedestrian model helps validate that theory while also allowing further testing to occur. Though not yet in use, the model has the potential to apply to other communication methods and provide a more realistic understanding of how communication would occur in an actual emergency as opposed to a fictional one. Figure 11 shows how contact rate affects method spread as the blue dots change to red when the message is effectively spread.

Discussion

Though all the communication systems are shown differently, exploring communication contact rate as a key to effectiveness will need to be considered in following trials. For example, text message systems have the potential to be most effective evacuation communication method as it can reach most and is still accessible those with disabilities and those who are not the in the main arena of the stadium, where visual and audible public announcement systems are used. However, a possible issue is that the number of patrons on their phones could overload the cellular signal and the test message does not go through, cancelling all the benefits (CDC, 2014).

Audible public announcements are the next most effective evacuation communication method. This method is also beneficial in reaching all patrons, not only those who are in the main arena. However, the consideration of those with special needs should occur as this method does hinder those who are deaf or hard of hearing. Also, audible public announcements need to be cautiously used, as an aggressive amount of loud and commanding announcements could increase patron panic and induce anxiety attacks. Testing will follow to see how valid this system is to the actual evacuation.

Finally, visual public announcement systems are the least effective of all three methods but the best considering understanding. This method can only reach patrons who are in the main arena and those who can read, observe, and understand the screens available. It does not take blind patrons into consideration. However, if the visual public announcement is flashed on and off, it could draw more attention to the message. Additionally, more information could be given via visual public announcement systems, and it could be easier for information updating.

Conclusion

Though examining the results appears to suggest that the visual public announcement system was the most effective model. However, it only reaches a certain number of patrons at one time. Therefore, all methods of communication uses three reliable systems to issue an evacuation message. However, the message would need to be uniform and accurate for this model to work. While it is not feasible for all three methods to be consistently running at the same time, each situation would require a specific combination of the three. This question will require more consistent testing to deduce the correct order and should be used in combination with the pedestrian model to achieve the most realistic results. As testing continues, this same question will apply to the pedestrian model and contact rate. Incorporating social media as a communication method will be considered moving forward. However, this method has more complex intricacies, obsolescence being a distinct possibility.

Notably, many of these systems can be altered to ensure that they perform more effectively than their standards. These differences may mean that one system is more effective than another at a certain venue, event, or scenario. These alterations continue to affect word-of-mouth communication; thus, all three methods should be considered in addition to this method. Word-of-mouth communication continues to be the communication at the base of each method, deciding effectiveness and understanding of evacuation. The faster a message is understood, the better the outcome of an evacuation. By assisting individual security, the venue is better prepared for an emergency. The faster they respond, the more lives saved. Therefore, communicating proper response to patrons is the difference between life and death.

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