Assessing the Effectiveness of Automatic Door Lock System by Discharge Detection to Lower Casualty during an Academic Active Shooter Incident

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Abstract

The 2018 Stoneman Douglas High School (Parkland) shooting emphasized the importance of active shooter preparedness for both the first responder communities and the general public. Since the 1999 Columbine Massacre, the preparedness for active shooter incidents (ASIs) proactively took place. Currently, the Run.Hide.Fight.® [2] (RHF) response for unarmed individuals is implemented as part of the active shooter response for the public and private sectors. However, despite the RHF's nationwide implementation, there is lack of literature that supports the effectiveness of RHF. Additionally, the Parkland shooting suggests the application of RHF without shooter's whereabouts could cause higher casualty rate.

This paper compares the casualty rates of two models. The first model only consists of Hide (*Shelter-In-Place*) and Run (*Evacuate*). The second model applies the first model's components with the automatic door lock system, which is triggered by the discharge detection. To exclude human participation to prevent physiological and psychological impact, the agent-based modeling (ABM) is used to recreate one story academic infrastructure with 26 lecture halls and 3 exits containing 600 unarmed individuals. The flexibility of ABM allows multiple iterations while manipulating various parameters. The ABM approach in an active shooter research also eliminates human error and logistical issues. The outcome of this paper evaluates the effectiveness of automated door lock system based on the firearm discharge detection with a campus-wide alert system to conduct lockdown.

1. Introduction

The term active shooter incident (ASI) may be a familiar term for the general public. The Federal Bureau of Investigation [4] statistics suggest the number of active shooter incidents has risen from 7.4 (2000 ~ 2008) to 19.1 (2009 ~ 2016) annual incidents per year. Additionally, 45.6% of the active shooter incidents occur in areas of commerce, and 24.4% in the educational institutions. Finally, 60% of ASIs are terminated prior to the law enforcement's arrival. The increasing rate of active shooter incidents in the areas of commerce and educational institutions with short duration challenges the first responder and the civilian communities to mitigate such incidents.

The law enforcement communities have applied mitigation tactics such as unified incident command system [5], hosting school resource officer [7], and formation of contact teams [7] prior to approaching the shooter. The most common ASI response for the civilian population in both the private and public sectors is Run.Hide.Fight.® [2] (RHF). The RHF response was created in 2012 by the City of Houston under Federal Emergency Management Agency's grant. Yet, despite the RHF's nationwide application, there is lack of literature that supports the effectiveness of RHF to lower casualties during ASIs. Additionally, RHF cannot be applied in areas where the unarmed individuals are incapable to *Fight* the active shooter such as kindergarten or elementary school.

This paper examines the casualty rates of two different models. The first model represents an academic infrastructure without any preventative system. The second model applies the first model with an automated door lock system, which is initiated by the active shooters first discharge. A campus-wide lockdown is automatically conducted among unarmed individual agents. The door lock system only prevents entry to the lecture hall which allows individuals to evacuate from the lecture hall. Both models only implement Run and Hide since the model assumes the majority of unarmed individual agents are either kindergartener or elementary school students, who are limited to fight the shooter.

2. Agent-Based Model

The AnyLogic software consists of three major components: discrete event, agent-based and system dynamic methods that could be used interchangeably. For this paper, the agent-based method will be predominantly used to recreate active shooter incidents within the educational environment. The model consists of pedestrian and process modeling libraries which recreates the interaction between an active shooter and the unarmed individuals within the model

The benefits of ABM is the ability to measure emergent phenomena which collect individual agent's interaction with other agents. Additionally, ABM can illustrate "behavior, degree of rationality, ability to learn and evolve" [1] which is a crucial component in measuring the cause and effect of hypothesizing what increased or decreased the casualty rate. Finally, using ABM allows the active shooter research to be conducted in a safe environment by eliminating the participants potential to experience "post-traumatic stress disorder or other anxieties" [3].

Both models are based on the blueprint of an anonymous higher education institution which was available publically available online as a visual aid for the emergency evacuation plan. The PDF plan was then converted to an image file and added to the AnyLogic.

3. Model Physical Infrastructure

The *Wall*, *Target Line*, *Service with Lines* and *Polygonal Area* from the Space Markup section in the Pedestrian Library was used to model the physical infrastructure. The *Wall* creates a physical barrier within the model which limits the agent's movement. For example, if a wall is encountered by an agent within the model, the agent seeks alternative routes by moving away from the obstacle. The *Service with Lines* can send an agent through the wall which represents an agent passing through the doorway. The *Polygonal Area* represents a lecture hall seats where the agents remain in one location during the class duration. Each lecture hall consists of one attractor as a point of gathering during the lockdown phase.

4. Model Agents

There are two agents in this model, an active shooter and the unarmed individual agents.

State Configuration – Line of Sight (LOS)

Each agent carries different states to add flexibility of what an agent could and could not do depending on the location. For example, just because an active shooter agent's discharge range is set to 100 feet does not mean that the shooter is capable of selecting targets through the wall of the lecture hall or agents in a different hallway section. To limit the target selection of the shooter, the *line of sight* (LOS) protocol is implemented.

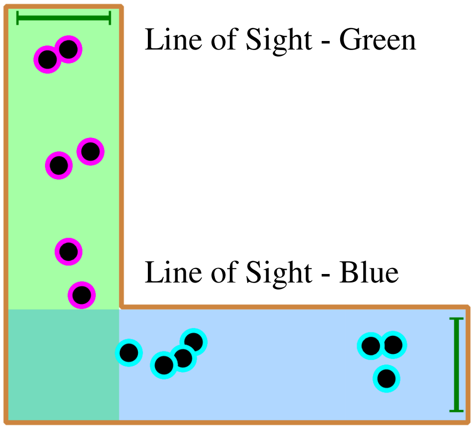

Figure 1: The Change of Agent's State by Location

The *line of sight* (LOS) was modeled by placing agents under different state depending on the location. In Figure 1, the agent's state under green LOS is colored purple. Once the agent enters the light blue LOS, the agent's state and color changes to cyan. Additionally, an agent could be under both green and blue LOS if two areas are merging. Both agents operate under this concept to limit the target selection probability based on the physical location such as hallways, and lecture halls.

State Configuration – Casualty

The active shooter agent selects the target by using a *Function* under the *Agent Library*. Each *Function* is coded in Java which selects the shooter target based on the LOS state followed by the discharge range. One target could be selected per search where the rate of each search is set to one target search per 21.176 seconds. The rate is based on the Parkland Shooting [6] by assessing total death count and the duration of the shooting.

The Java *Function* is divided into three sections. The first section is the target selection among agent's population. For instance, the shooter agent will search for one target among the pool of unarmed individual agents.

The second section of the function entails determining the state of the potential target agent. If an agent's state is a *casualty*, then the function starts over to find a new target. If the agent's state is not a *casualty*, then the function determines whether the target is within the same LOS state as the shooter. If the shooter and the unarmed individual is in the same state, then the function evaluates the discharge range. If the potential target does not qualify under either state, the function restarts.

The third section of the function executes the act of firearm discharge to the targeted agent. The exchange of fire is modeled by sending a string *message* to the targeted agent. The probability of a failed message delivery is zero since the execution will occur immediately. Once the message has been received, then the state of the target agent will change to *casualty* where the speed of agent will be set to zero and the color to red.

Agents Movement

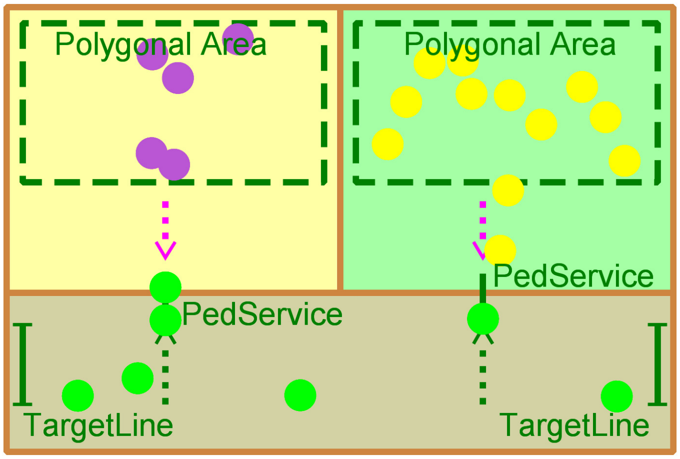

Figure 2: The Change of Agent's State by Location

The agent's movement is conducted by the following blocks from the Pedestrian Library: *PedSource*, *PedGoTo*, *PedService*, and *PedSink*. The *PedSource* determines the agent and the rate of entry from the agent to the model. For this model, there are two *PedSource* blocks, one for an active shooter and the other for the unarmed individual agents. The *TargetLine* is used as an entry point which is determined within the *PedSource* block. Once the agent exits the model by the *PedSource* block, the agent enters the *PedService* block which allows the agent to enter to the lecture hall. The *PedService* block prohibits the agent to travel through the wall which represents a door. Upon entry, the agent's state is changed in accordance with the lecture hall. Each lecture hall consists of a *Polygonal Area* where the agent waits throughout the model runtime.

5. Agents' Logic

Unarmed Individual Agents' Logic before Active Shooter Discharge

The unarmed individual (UI) agents enter the model and move toward the available lecture hall at a random choice. Once an agent arrives in the lecture hall, it will remain at the location throughout the model's duration.

Active Shooter Agent's Logic

The active shooter (AS) agent enters the model and continues to walk the hallway until the in-class population count reaches 600. The shooter begins to discharge to the unarmed individual agents while randomly entering lecture halls. The active shooter agent will continue to discharge until the model is terminated.

Automatic Doorlock System by Discharge Detection

The automatic door lock system begins as soon as the active shooter agent discharges their first shot. The system prevents the active shooter to enter while allowing any agent inside the lecture hall to evacuate.

Unarmed Individual Agent's Logic after the Active Shooter Discharge

The active shooter's discharge initiates the unarmed individual agents to either Hide (*Shelter-In-Place*) or Run (*Evacuate*) from the shooter. The Hide probability parameter determines how many percentages of unarmed individuals will hide while the rest will run from the shooter. In Table 1, if the hide probability is set to 20%, then the remaining 80% will run toward the nearest exit.

Table 1:

Parameter (P)	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Hide (%)	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Run (%)	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%

6. Model Runtime Properties

Model Limitations

- The duration of the model is limited to 6 minutes which is equivalent to the Parkland Shooting [6].

- The rate of casualty is limited to one casualty per 21.176 seconds based on the Parkland Shooting [6].
- The target selection begins once all 600 unarmed individuals are placed within the lecture halls where the first casualty is always caused in the lecture hall which limits the shooter's ability to select targets in the hallway.
- If there are no potential target upon 21.176 selection duration, the shooter requires additional 21.176 seconds to select another target.
- The unarmed individuals who are Hiding in the lecture hall do not attempt to escape if the shooter enters the lecture hall.

Model Interations by Parameter Manipulation

Each hide parameter is run 100 iterations measuring the following data output:

- Hide probability (Double)
- Number of unarmed individuals in the lecture hall (Integer)
- Number of unarmed individuals in the hallway (Integer)
- Number of unarmed individuals casualty (Integer)
- Number of unarmed individuals who successfully evacuated (Integer)
- Number of lecture hall casualty of unarmed individuals (Integer)

7. Results

The Figure 3 and Figure 4 compares the casualty rate of unarmed individuals by the Hide (*Shelter-In-Plance*) probability. Three different casualty rates are illustrated on both figures of total, hallway, and lecture hall.

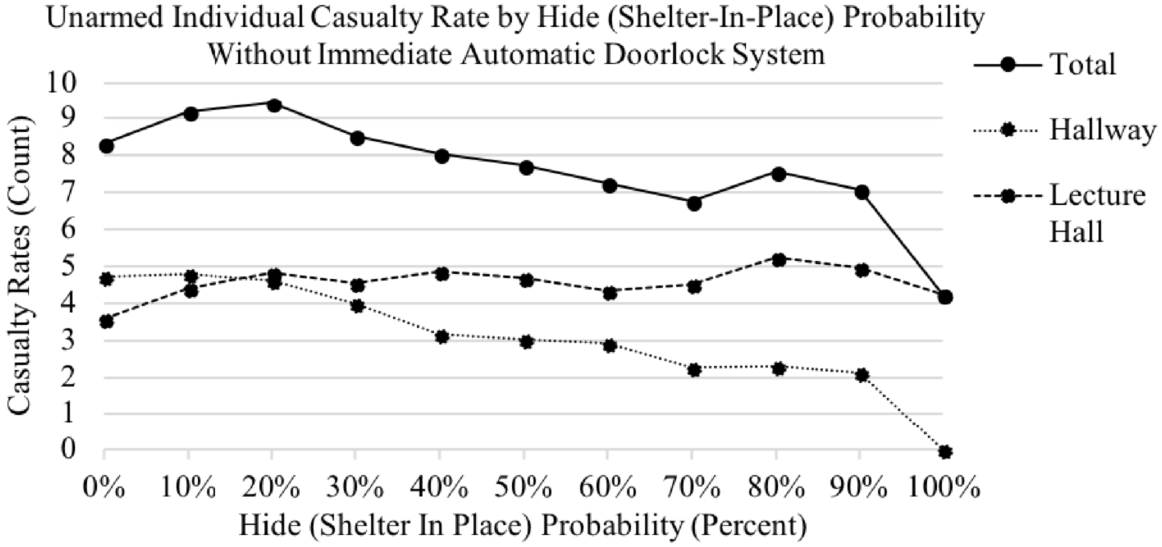

Figure 3: Unarmed Individual Casualty Rate by Hide (Shelter-In-Place) Probability Without Immediate Automatic Doorlock System

Figure 3 suggests the highest average total casualty rate of 9.43 by 600 (1.57%) where 20% hid and 80% ran to the nearest exit. The lowest average total casualty rate was 4.23 by 600

(0.71%) where all unarmed individual agents are seeking shelter within the lecture halls. The highest average hallway casualty rate was 5.24 by 600 (.87%) with 80% hide probability where the lowest rate was 3.60 by 600 (.6%) with 0% hide probability. The highest average lecture hall casualty rate was 4.79 by 600 (.79%) with 10% hide probability with the lowest at 0 by 600 (0%) with 100% hide probability.

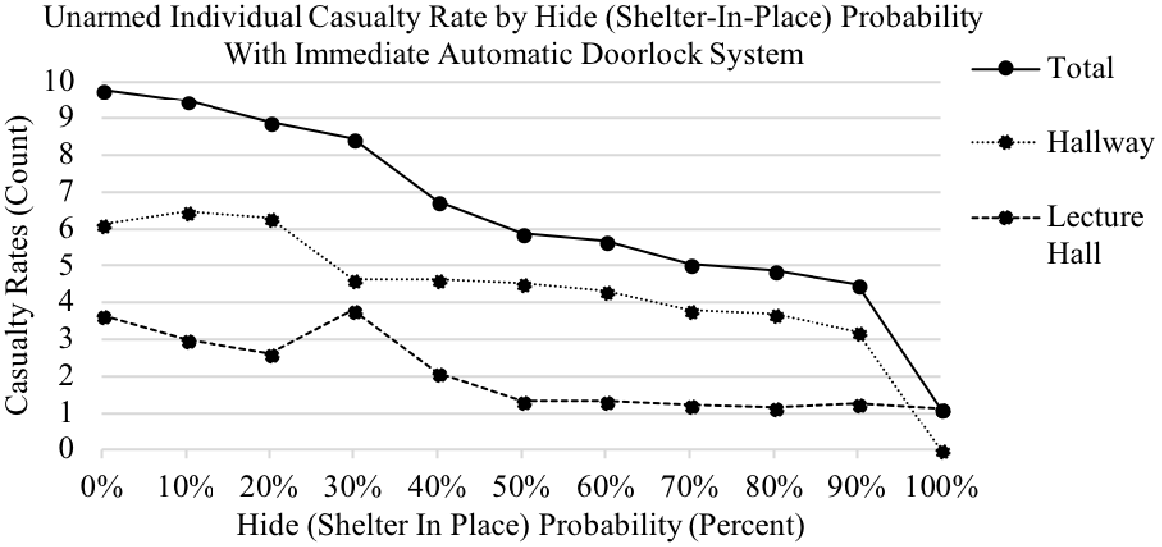

Figure 4: Unarmed Individual Casualty Rate by Hide (*Shelter-In-Place*) Probability with Immediate Automatic Doorlock System.

Figure 4 suggests the lowest average casualty rate of 1.15 (0.19%) is reported when all unarmed individuals hide from the shooter with the automatic door lock mechanism in place. The highest average casualty rate was 9.8 (1.63%) where all agents had to evacuate from the lecture hall regardless of the automated lock mechanism. The highest average hallway casualty rate was 6.47 by 600 (1.08%) with 90% hide probability where the lowest rate was 0 by 600 (0%) with 0% hide probability. The highest average lecture hall casualty rate was 3.81 by 600 (.64%) with 30% hide probability with the lowest at 1.15 by 600 (.19%) with 100% hide probability.

The Figure 5 and Figure 6 compares the casualty probability of unarmed individuals by the Hide (Shelter-In-Plance). Three different casualty probabilities are calculated by dividing the casualty rates of total, hallway and lecture hall to the total number of participating unarmed individuals. For example, hallway casualty probability is calculated by dividing casualty rate by the total number of evacuees to the nearest exit.

Figure 5: Unarmed Individual Survival Probability by Hide (Shelter-In-Place) Probability Without Immediate Automatic Doorlock System

The highest total casualty probability is 1.57% when 20% of unarmed individuals hide. The lowest total casualty probability was .71% when 100% evacuates to the nearest exit. The lecture hall casualty probability was the highest at 7.35% when 10% of the unarmed individuals evacuated. The lowest lecture hall casualty probability was at .6% when everyone checked sought shelter. The highest hallway casualty probability was 3.53% when 90% hid upon the first discharge. The lowest hallway casualty probability was 0% when 100% hide from the shooter.

Figure 6: Unarmed Individual Survival Probability by Hide (Shelter-In-Place) Probability With Immediate Automatic Doorlock System

The highest total casualty probability was 1.63% when all 600 unarmed individuals evacuated to the nearest exit. The highest lecture hall casualty probability was at 5% when 10% hide from the shooter where the lowest probability was .19% when all unarmed individuals hid in the lecture hall. The highest hallway casualty probability at 5.36% when only 90% hides from the shooter. The lowest hallway casualty probability was 0% when all unarmed individuals hide.

8. Conclusion

The implementation of an automated doorlock system triggered by the discharge detection does decrease the total casualty rate on average of 1.24 rate in this model while considering the limitations. Additionally, the total lecture hall casualty rates are also decreased to an average of 2.50. In contrast, the total hallway casualty rates were increased by 1.26. The model suggests that the active shooter's duration in the hallway increases since the shooter is unable to make entry to the lecture hall. This circumstance increases the casualty probability for the unarmed individuals who are attempting to evacuate to the nearest exit.

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