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The optimization of emergency call systems using simulation modeling

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THE OPTIMIZATION OF EMERGENCY CALL SYSTEMS USING SIMULATION MODELING

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To my mother, Debra – for her sacrifice and continued motivation and support in my pursuit of academic achievement.

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time as an athlete ended and I began to seek a career and major, it was her knowledge and guidance that steered me toward a career in technology in which I gained a strong passion for. I am very thankful and blessed to have her as a parent.

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NG-911 – Next Generation 9-1-1

GLOSSARY

discrete-event modeling – a system that models the operation of a system as a discrete sequence of events in time.

emergency call box – “phone towers that provide immediate help to those who need it and to effectively facilitate the documentation of an incident as it happens” (Colombo, 2006, ¶ 6).

emergency reporting – “victims ask for help by reporting emergency conditions through emergency call to the Public Safety Answering Point (PSAP)” (Tsai et al., 2011, p. 97).

mobile safety system – “transmit real-time GPS location and provide two-way communication with private security, 911 authorities and safety groups” (Guardly, 2014).

modeling - “the processes of mapping the problem from the real world to its model” (Borschev et al., 2001, p.1).

simulation – “the process of model “execution” that takes the model through (discrete and continuous) state changes over time” (Borschev et al., 2001, p.1).

ABSTRACT

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Using computer simulation modeling, this research assessed the effectiveness and response times when using a mobile safety system versus an emergency call box when reporting an emergency at Purdue University, West Lafayette's Engineering Mall area, attempting to answer the first question "What emergency call system is more effective: a mobile safety system or an emergency call box ?" The second question asks "What emergency call system has a faster response time: a mobile safety system or an emergency call box?" A discrete event simulation model of the emergency call service is used. The outcome of the study was that the mobile safety solution resulted in being more effective than the emergency call box. This study shows that the arrival time to reach an emergency call box is a major factor in lowering the average effectiveness time when using an emergency call box to report an emergency. This study shows that the emergency call box results in an average overall faster response time when reporting an emergency versus using a mobile safety system. This study uses a simulation approach that produces a decision tool for

campus security officials to assess emergency call systems effectiveness and response times on a college campus.

CHAPTER 1. INTRODUCTION

1.1 Problem Statement

Emergency dispatch personnel are usually faced with significant challenges when responding to an emergency call. Currently, the dispatcher has to effectively gather accurate information through in depth conversation, lacking real-time information, which could result in delayed response times. In addition, the emergency responders lack real-time awareness of the situation, which may cause an increase in time between dispatching emergency responders and ending the incident.

At the current time, most emergency response officials are not taking advantage of emerging mobile safety technologies, and are still relying on public safety communications that are primarily voice-only applications. In particular, for emergency calling, college campuses typically rely on two-way voice blue light phones that have stationary limitations and incur costly maintenance fees, are used mistakenly, and Wireless Enhanced 911 (E911) that does not provide real-time location accuracy(Guardly, 2014). Increased smartphone adoption among the public and the evolution of fourth generation networks (or 4G) has provided opportunits for the implementation of next-generation mobile safety systems that provide similar functionality as traditional security technologies, as well as added services that could decrease security costs, enhance decision-making, and improve incident response times.

Therefore, the purpose of this research was to benefit university Chief Security Officers in their evaluation of implementing a next-generation mobile safety solution as the primary resource of emergency calling and response on a college campus. It assesses emergency response times and the effectiveness of using a next-generation mobile safety solution that provides real-time mobile location data tracking and other identifying information versus using an emergency call-box on the Purdue University college campus' Engineering Mall using simulation modeling.

1.2 Research Question

- What emergency call system is more effective: a mobile safety system or an emergency call box?
- What emergency calling system has the fastest overall response time: a mobile safety system or an emergency call box?

1.3 Scope

In this research, a discrete event agent-based model of Purdue University's Engineering Mall was used to evaluate the effectiveness and overall response time when using a mobile safety system for emergency calling and response versus an emergency call box. Testing involved working within the computer simulation software, AnyLogic. The goal was that the findings of this research would give Chief Security Officers an assessment tool to evaluate implementing a next generation mobile safety solution as a part of their emergency reporting methods on campuses. The scope of the research was to determine if there would be any significant changes to incident response times when using the next generation mobile safety system versus incidents reported and responded to using call boxes using simulation modeling on the Purdue University, West Lafayette campus Engineering Mall.

1.4 Significance

Reporting an emergency on campus has traditionally been limited to emergency call boxes, using a cell phone, and walk-ins at the security dispatch desk. Because of the stationary limitations of the blue light phones, and the inability of typical mobile phones to track a mobile caller's location in real-time, next generation mobile safety solutions have emerged. The increase of mobile phones across the public is correlated to the increase in campus police calls from these devices versus landlines or emergency call boxes (Guardly, n.d.). The purpose of implementing a next generation mobile safety system was to enable students to quickly alert and communicate with security dispatch in any situation, anywhere on campus grounds. The services that these mobile safety systems will provide are predicted to reduce emergency response times on campus.

A similar study conducted by Guardly (2014) was conducted for assessing response times with a next generation mobile safety solution. However, a major process in the entire system was omitted in that study. In particular, the study does not take into to consideration if an individual in need is at the exact location of an emergency call-box at the exact time of the emergency. The current study will aim to provide an assessment tool to provide security officers for the evaluation of emergency response times on campus when using a next generation mobile safety system versus using an emergency call box for emergency calling and responding, including the time between an emergency occurring and arriving at the emergency call-box.

1.5 Assumptions

The following assumptions were made in the study:

- The dots representing pedestrians and pedestrian speed used in the model could accurately represent each individual with enough specificity for the model to be accurate.
- The model image replicated in AnyLogic accurately replicated the Purdue University, West Lafayette Engineering Mall.

1.6 Limitations

The following limitations were made in the study:

- The experimental study assumed the emergency call was made on the Purdue University, West Lafayette campus.

- The experimental study assumed the emergency call was made in the Purdue University's, West Lafayette Engineering Mall.
- Total response time results only included the time between the emergency occurring and the security arriving at the individual person in need location.

The study assumes there is a safe area within the Engineering Mall when using an emergency call box.

1.7 Delimitations

The following delimitations were made in the study:

- No special cases were injected into the model in this study.
- All emergency scenarios were treated as the same.
- After reporting the emergency call from an emergency call box or mobile safety system , it is assumed that the emergency caller remained at the same call location.

1.8 Chapter Summary

This chapter introduced challenges with the current dispatch process using a stationary emergency call box and how next generation mobile safety systems could improve those challenges. In addition, the chapter outlined the scope and significance of the research and the associated assumptions, limitations, and delimitations.

CHAPTER 2. LITERATURE REVIEW

This chapter gives an overview of current challenges of emergency calling and dispatch systems. It then reveals the evolution of mobile devices, because it will provide Chief Security Officers awareness of certain capabilities and security services they could implement by utilizing mobile safety solutions. Finally, this chapter explains next-generation mobile safety solutions and how certain features could improve emergency response times on a college campus. The goal of the chapter is to provide insight into how next-generation mobile safety systems could improve the emergency calling and dispatch process on college campuses versus existing security methods using simulation modeling.

2.1 Challenges of Emergency Calling and Dispatching Systems

Since the Virginia Tech shootings in 2007, campus security officers have changed their outlook on campus safety. West and Valentini (2013) declare, "In recent years, universities have invested big dollars into mass notification systems, adding layers of needed redundancy such as digital signage in classrooms and meeting areas, indoor and outdoor sirens, social media outlets like Facebook and Twitter, computer pop-ups, and wireless alerts" (p.8). Security officials have also invested in new security systems for emergency calling. Emergency call boxes have also been implemented on college campuses throughout the United States. These emergency call boxes are intended to minimize the opportunities for crimes and maximize the potential for law enforcement to discover incidents as they occur (Colombo, 2006).

However, they are rarely used for legitimate safety reasons (Twyman, 2013). “Randy Young, spokesman for UNC’s Department of Public Safety, said the boxes are used only a handful of times a year and on average used once every few months for situations where students are in danger” (Twyman, 2013, ¶ 2). A 2009 report by the University of California, Davis task force found that “of 324 calls made to dispatch from these phones in an 18-month period in 2006-07, none was considered life threatening” (Easley, 2011, ¶ 12). Data made available from Jeanne Clery Disclosure of Campus Security Policy and Campus Crime Statistics Act show patterns of “light crime” at the Purdue University, West Lafayette campus (“US Dept. Edu.,” 2012). In a personal interview, Purdue University Captain Eric Chin stated that “there are times however where they are activated and no one is on the line. For those incidents, from August 2013 through April 2014, there have been 150 of those incidents” (E. Chin, personal communication, April 9, 2014). Most emergency calls from these phones are for flat tires or safety escorts, and hang-ups (Easley, 2011).

Emergency call box technology and features also have costly maintenance fees. At the University of North Carolina, “there are 112 call boxes on campus that cost $6,900 to maintain and monitor per year, and the cost of powering the boxes is about $2,690” (Twyman, 2013, ¶ 3). At Contra Costa

Community College District, which has almost 62,000 students in the San Francisco Bay Area, the 25 or so emergency call boxes from its three campuses cost about $50,000 annually for upkeep (Moltz, 2010). As security officials wrestle with increasing security costs, while providing a safe campus, dramatic reductions in state funding are also a major barrier (Moltz, 2010).

The introduction of wireless 9-1-1 provided a convenient and efficient method of alerting the police in the case of an emergency. Easily (2011) states, campus wireless 9-1-1 “routes calls according to the cell site receiving and transmitting the signal, and local cell site antennas are directed toward the campus dispatch center” (¶ 11). However, Wireless Enhanced 911 (E911) does not provide a dispatcher with the ability to track a mobile caller’s location (“Campus Safety,” 2014). According to the US FCC requirement, “Wireless E911 may take up to 6 minutes to report a caller’s latitude and longitude to authorities” (“Campus Safety,” 2014, p. 1).

There still remain significant challenges in the interoperability of the communication methods for public safety. West and Valentini (2013) declare that “the importance of such communication was highlighted by the shootings at Columbine High School in 1999” (p.9). In a January 2008 Report of the Campus Safety Task Force Presented to Attorney General Roy Cooper, “first responders are dependent on fast, reliable communications during and after national tragedies and natural disasters” (“Report,” 2008).

2.2 The Evolution of Mobile

Chief Campus Security Officers have yet to significantly embrace the emerging adoption of mobile devices by the public, especially smartphones. In a recent Ball State University (2013) study, 73 percent of students reported using a smartphone as compared to 27 percent in 2009. It is projected to increase to 90% by 2014, according to the Ball State University study. As for adults, smartphone penetration at the end of 2012 was 54 percent (Ball State University, 2013). According to the Cisco Visual Networking Index, global mobile data traffic has doubled for the fourth year in a row ("Cisco Visual," 2013). It is estimated that "global mobile data traffic will increases 18-fold between 2011 and 2016. By the end of that time period, 10 billion mobile devices are projected to be in use around the world" (West & Valentini, 2013, p. 1).

Mobile devices have continued to provide mobile developers the opportunity to create mobile applications that could enhance ones' life professionally, as well as personally. Mobile applications and "smarter" features that help people save time, navigate, take photos and videos, and make smarter decisions, are now being used more than placing and receiving phone calls (Guardly, 2014). Gartner research predicted that 102 billion downloads would take place by the end of 2013, up from 64 billion in 2012 (Guardly, 2014).

2.3 Next Generation Mobile Safety Systems

In the last several years, there has been much mobile technological innovation in homeland security and public safety, especially for campus safety.

Since the Virginia Tech shootings, which left 32 people dead and 17 more injured, mobile technology invention and applications have improved considerably (West & Valentini, 2013). Mobile technologies have evolved to the fourth generation (4G), resulting in next generation mobile applications being developed with more underlying technology. These next generation mobile safety solutions have provided security officials additional safety services that once were not available to them.

Next Generation E911 (NG911) has the capability of enhancing the overall experience of emergency reporting and response. "In contrast to the legacy 'voice-centric E911 network, Next Generation E911 (NG911) will support a more diverse set of IP-based communications including text, data, photos, and video exchanges that will enhance the speed, accuracy, and preparation of first responders" (Iadarola, 2012, ¶ 1). As a result, next generation mobile safety systems have emerged. The University of Chicago has launched a smartphone app called Pathlight that allows students to opt in to GPS tracking services (West & Valentinini, 2013). At the University of North Carolina at Charlotte, a new application called the Effective Emergency Response Communication (EERC) System for iPod Touches was tested in 2012, as well as Northwestern State University launching a Personal Guardian application that allows users to opt-in to a feature that tells police where they are going and when they arrive ("Wash. District Implements," 2012).

The mobile safety systems are primarily composed of two major software components, a web-based incident management system and mobile applications

("Campus Safety," 2014). A web-based incident management system "helps dispatch personnel to monitor, manage, and respond to emergencies within their campus boundaries" ("Campus Safety," 2014). An emergency dispatcher will have enhanced capabilities in regards to situational awareness of the incident. The web-based incident management system will enable the dispatcher to view the real-time location of the caller on a map interface along with the context information about the caller (Krishnamoorthy & Agrawala, 2012). Geolocation and situational awareness is especially important in emergency situations for an emergency dispatcher. In a previous study regarding public safety mobile applications requirements, based upon feedback from Public Safety personnel, it was essential that the application provide location information to the user, enabling basic situational awareness (Erickson, et al., 2013). The ability to have real-time caller location from the dispatcher point of view is critical. In a previous study, dispatchers used mobile location data, caller identification and profile, and phone features in 96% of incidents ("Campus Safety," 2014).

The mobile safety application will redefine how emergency calls are presently made (Shivsubramani & Agrawala, 2011). The mobile application will provide certain services to the caller that could be the difference of saving their life, including the ability to have real-time location-based tracking services, photos for enhanced situational awareness, and other profile information of the user. Mobility, along with real-time tracking is a significant advantage when using a mobile safety application. Real-time location tracking allows dispatchers to track callers even if they need to move from the initial location. In some cases, emergency callers may not be able to use their voice, and therefore real-time tracking becomes very important for dispatchers to monitor the situation. The positive impact of NG911 technologies could be lifesaving. The ability to see photos or video of an incident would provide more detail to responders (Goforth, 2012). Goforth et al. (2012) also mention that the ability to see photos or video adds more validity to the emergency situation instead of relying on the caller's perception for information. The photos also allow a dispatcher to have better situational awareness. Wu, Yan, and Zhang (2011) declare, "photos, as a type of rich, accountable, and generally comprehensible information carrier, are perfect to facilitate communication" (p. 2).

2.4 Simulation Modeling

Efficiently planning the approach for emergency response is a critical component of emergency management, especially on college campuses were there could be thousands of individuals in a compact area. Investments and the implementation of emerging safety technology is a critical decision among security officials. Therefore, accurate testing of these new technologies is very important to the Chief Security Officers' duty of providing effective emergency calling solutions for public safety on college campuses. A simple and cost-effective process to test the implementation of new technologies in a process before investing is to create a simulation model.

Emergency response simulation and modeling is being frequently suggested as the key ingredient for emergency response preparedness (Jain &

McLean, 2003). Business process modeling has long been used to evaluate the implementation of new technologies and how to determine how it would affect the business service. Jain and Mclean (2003) explain that emergency response planning tools allow evaluation of alternative strategies to respond to a disaster event. A popular simulation modeling tool is AnyLogic. AnyLogic can be used in different application problems, such as "epidemic spread modelling, industrial development, complex system design evaluation, computer performance evaluation, military systems, transportation systems, supply chain management, and business process evaluation" (Merkuryeva & Bolshakovs, 2010, p. 169). This research will involve the use of AnyLogic 6, which is Java language based. It has an embedded tool named OptQuest, which is used for optimisation.

This research involves a pedestrian flow. A pedestrian or individual that encounters an emergency situation will react and either find the nearest emergency call box or use their mobile device to dial the emergency number. The pedestrian will then request for service and wait until the security officers arrive to end the incident. The most recent and emerging type of modeling is agent-based modeling. Agent-based modeling entails modeling as a "collection of autonomous decision-making entities called agents" (Bonabeau, 2002, p. 7280) Agent-based modeling presents many benefits, as it can also be combined with discrete-event modeling and system dynamics. It "captures emergent phenomena", "provides a natural description of a system", and "is flexible" (Bonabeau, 2002, p. 7280). However, agent-based modeling has its weaknesses, as it still challenging to depicting a variety of individuals such as age, the familiarity of the environment, or any other factor that could represent different groups of people.

2.5 Previous Research

In a previous study that assessed emergency response times on a campus when using *Guardly Mobile Application*, a next generation mobile safety solution, resulted concluded that the mobile solution provided an overall reduction in response time by 44% per incident ("Campus Safety," 2014). The study generated control data from live emergency scenario simulations. The test involved comparing 27 real emergency scenarios data that occurred with an immediate emergency response (control group) against experimental data that involved campus security "recreating, re-enacting and simulating each of the 27 incidents, mimicking the location of the emergency call, situation at hand and other incident-specific attributes" ("Campus Safety," 2014). However, the response times were divided into two incident response periods. The first period involved the time difference between receiving an incoming call and dispatching security personnel. The second period involved the time difference between dispatching security personnel and ending the incident. The first time period resulted in a "total average time elapsed for that period decreased from 67 seconds to 33 seconds when using *Guardly Safe Campus"* ("Campus Safety," 2014, ¶ 6). The second time period resulted in a "total average time savings of 43% (7:37 minutes) was observed, as total average time elapsed for that period decreased from 17:27 minutes to 9:50 minutes when using *Guardly Safe Campus*" ("Campus Safety," ¶ 6).

It is important to note that this study does not discover the time it takes to locate the nearest emergency call box in an emergency situation. Locating an emergency call box is critical sub process within the entire process as it is possible that the individual may not be located near or within sight of an emergency call box when an emergency occurs. The results showed a favorable decrease in overall response time when using the Guardly Safe Campus. However, this led to future research in determining response times within a particular area of a college campus and the total response time, including the required time it takes to locate an emergency call box using an AnyLogic model.

2.6 Chapter Summary

This chapter summarized the challenges of current emergency calling and dispatch systems, the evolution of mobile, next generation mobile safety solutions, previous emergency response time research on a college campus, and the need for simulation modeling. It shows that previous research has been conducted in the area of utilizing mobile technology versus existing security systems for emergency calling and response, but little research has been done in modeling of these systems. It showcases the ability for Chief Security Officials to take advantage of the dramatic increase in smartphone adoption, especially among college students. Therefore, a simulation needs to be performed comparing the effectiveness of the next generation mobile safety system versus an emergency call box in a particular area of a college campus that showcases pedestrian speed to locate an emergency call box and the overall response time when including all sub processes in the entire process of an emergency call and response. In return, this research can provide data for similar sized areas on a college campus and help improve overall response times and effectiveness.

CHAPTER 3. METHODOLOGY

This chapter discusses the research framework and testing methodology, tools of measurement, and the variables used in this thesis.

3.1 Research Framework

Using simulation modeling, this research involved a quantitative study to determine the effectiveness and overall response time for emergency calling and response on Purdue University West Lafayette's Engineering Mall area when using an emergency call box versus a mobile safety system. An aerial image of Purdue University's Engineering Mall was used for the simulation testing. The university engineering mall is an area within the campus that has 12,000 students that visits the area per day. This area possesses three emergency call boxes. The research resulted in an experimental design. The effectiveness and the overall response times of using an emergency call box versus a mobile safety system was compared using the Purdue University Engineering Mall area as the testing site. The environment of the experiment was controlled since it is within the simulation software, AnyLogic.

The independent variables that were optimized included:

- Time needed to get to emergency call box when selected for reporting an emergency.

- Time needed when using the emergency call box for requesting service.
- Time needed when using a mobile safety system for requesting service.
- Time needed between dispatching the police and arriving to the person in need.

Independent variables were determined through prior research. The fundamental variables in this research that will change is the distance to arriving at the call box within the Engineering Mall when reporting an emergency using a call box. The dependent variables in the study is the total operating response time when using an emergency call box and the total operating response time when using a mobile safety system and the overall effectiveness time. When using an emergency call box, the effectiveness time involves arrival time to the call box, dialing time, and dispatching police. The effectiveness time when using a mobile safety solution involves, first locating a safe enough area to make the phone call, dialing, and dispatching police. The safety area when waiting for the police is a designated area when using an emergency call box. When using a mobile safety solution, the waiting area is random. The study used 200 trials to test the hypotheses. The first hypothesis focused on determining if simulation modeling could show if using a using a mobile safety solution provides a faster response time than using an emergency call box after when reporting an emergency at Purdue University's Engineering Mall area. The second hypothesis focused on determining if a mobile safety system is more effective than an emergency call box when reporting an emergency at Purdue University, West Lafayette's Engineering Mall area. The values used for each sub-process were collected from previous research. The hypotheses included:

- H_{o1} Simulation modeling shows that using a mobile safety system for emergency calling and response does not change the response time when using an emergency call box.
- H_{a1} Simulation modeling shows that using a mobile safety system for emergency calling and response provides a faster response time than using an emergency call box.
- H_{a2} Simulation modeling shows that using a mobile safety system for emergency calling and response provides a slower response time than using an emergency call box.

- H_{o2} Simulation modeling shows that using a mobile safety solution has the same effectiveness time for emergency calling and response as using an emergency call box.
- H_{a3} Simulation modeling shows that using a mobile safety solution is more effective for emergency calling and response than using an emergency call box.
- H_{a4} Simulation modeling shows that using a mobile safety solution is less effective for emergency calling and response than using an emergency call box.

3.2 Testing Methodology

This research environment involved a discrete-event based model created within AnyLogic that represented Purdue University's Engineering Mall. AnyLogic is a proprietary simulation software that allows users to combine three simulation methodologies: system dynamics, discrete-event and agent-based modelling (Merkuryeva & Bolshakovs, 2010). A discrete-event model was used because this testing environment represents a system with multiple sub-systems that changes the entire system (Kirby, 2013). A discrete-event model can change based on an event within the model. This model involves a chronological sequence of events that change constantly. As a person encounters an emergency situation, they go through a sequence of events ranging from walking to an emergency call box, making the call and requesting for help, and waiting for security to respond. After two hundred trials, the data provided is supported by research and the experience of professionals in the public safety field. The model is a simulation that compares the effectiveness and overall response times of campus emergency calling security systems.

The flow diagram for the model is shown in Figure 3.1, as it served as the foundation for creating the AnyLogic model.

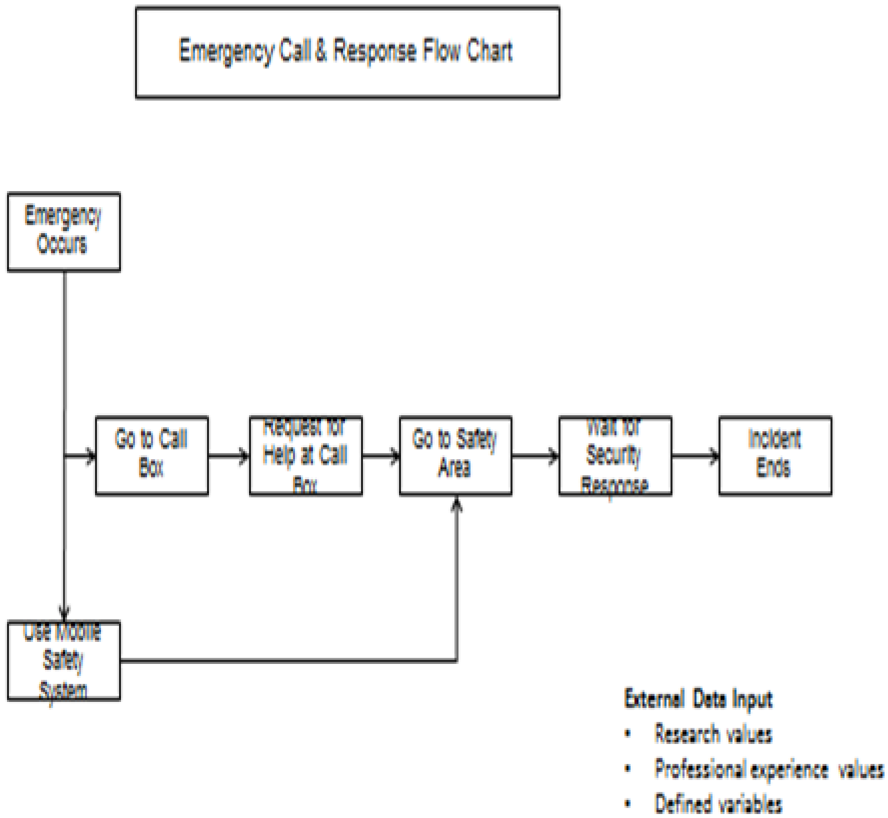

Figure 3.1. Emergency Call & Response Flow Chart

AnyLogic was chosen as the modeling software because of its ability to simulate discrete-event, agent-based, and system dynamics simulation. The AnyLogic software has a powerful Pedestrian Library, which allows the user to create a model with pedestrian speeds already programmed into the software. As this model entails pedestrians walking to an emergency call box and walking to a safety area on the Purdue University's Engineering Mall, this library was best suited for this testing. The program treats each pedestrian as a small dot walking through each individual process, which would be recorded in a Microsoft Excel spreadsheet (Kirby, 2013). Discrete-event modeling was used because it contains smaller systems that are a part of a larger system. The overall response time was important, although each smaller process effects the overall response time. The study integrated elements such as Systems Dynamics (for creating parameters), Analysis (for gathering data), and Presentation (for creating the UI and environment).

Appendix A shows the three main parts of the model via screen capture. A person that has an emergency decides if they will use an emergency call box or a mobile safety system to report the emergency. If a person chooses to report an emergency using a call box, then the person will go to a call box. The person will locate the closest call box queue from the initial starting point. While at the call box, the person will dial two digits to send the call, receive a response, and then request for help. After the request for help ends, the person will go to a designated safety area within the Engineering Mall and wait for security response. The end service of the *PoliceEndRoute* is the overall response time.

If a person chooses to report an emergency using a mobile safety solution, then the person will go to an area in which they feel safe enough to report the emergency. The person will dial, assuming they have a four digit passcode on the smartphone, receive the dispatcher response, and request for help. After requesting for help, the individual will go to a random safe area and wait for the police response. The model resumes the same process as the emergency call box after this object. The pedestrian model requires that you have an entry and exit point in the model. For this study, the entry line varies from random distances, and some circumstances where an individual may need to activate more than one call box, if needed. The estimated distances from the closest call box included:

Table 3.1. Distances from Call Box

Long Distance	Medium Distance	Short Distance	Multiple Call Boxes Activated
greater than 40 meters, estimated	20 – 40 meters, estimated	0 – 20 meters, estimated	Varied

3.3 Chapter Summary

This study covered the quantitative research framework, the testing methodology, the variables being tested, and the hypotheses being tested. It also discusses the testing tool used with its methodology.

CHAPTER 4. RESULTS

The purpose of this study was to assess the overall emergency response time when using an emergency call box versus a mobile safety solution at Purdue University's Engineering Mall. The study also assesses the effectiveness of each of these methods. The distance from an emergency call box was optimized. Overall emergency response time was the dependent variable that depended on other sub-processes of the entire process.

4.1 Initial Inputs and Parameters

Independent variable values were gathered from previous research and discussion with experts in the field of public safety at Purdue University. Independent variables for an individual using an emergency call box for emergency calling included:

- Time needed to arrive at an emergency call box
- Time needed between dialing and receiving a response
- Time needed between requesting help and dispatching security
- Time needed for security response

Independent variables for an individual using a mobile safety system for emergency calling excluded the time needed to arrive at an emergency call box. The data used was as follows:

Table 4.1. Input Parameters

Parameter	Number Used	Source
Pedestrian Speed	.5 – 1 meters/sec.	AnyLogic
Call box emergency dial and dispatcher response process time	5 sec.	estimate
Call box time between requesting for help and dispatching security	20 – 40 sec.	E. Chin, personal communication, April 9, 2014
Probability that an emergency caller activates multiple call boxes	0.10	estimate
Mobile safety system emergency dial and dispatcher response process time	10 sec.	estimate
Mobile safety system time between requesting for help and dispatching security	23 – 43 sec.	Guardly. (n.d.).
Purdue University Police response time	60 – 240 sec.	Purdue University, Purdue Police Department, 2014

For variables that were undeterminable for various reasons, best estimates were used (Kirby et al., 2012). Pedestrian speed is a built in function within the AnyLogic Simulation Software, and therefore did not a direct input. It was assumed for this model, that pedestrian speed is not varied at any time during the entire process. The call box emergency dial time until the dispatcher response was estimated, as there was no current data on time for dialing and dispatcher responding using an emergency call box. Purdue University Police Captain Eric Chin stated that the time between receiving an emergency call and dispatching the police was less than 30 seconds. Therefore, a range was used for this time.

The probability that an emergency caller activates multiple call boxes in the case of emergency was set at .10. This estimate is based off of the knowledge and research that there are rarely real emergency situations in which an emergency caller activates a call box. It is assumed that the only time an individual would need to activate more than one emergency call box is in real emergency situations. A Guardly Incorporated campus safety case study revealed that there was an average time of 33 seconds between receiving an emergency call and dispatching the police. Therefore, a range was used for this time. The mobile safety system dial time until the dispatcher response was estimated, as there was no current data on time between dialing and receiving a response when using a mobile safety system. Purdue University, West Lafayette Police Department stated that they have an average response time of less than two minutes, and therefore a range was selected for this process time.

4.2 Call Box Arrival Time

This study involved the process time of an individual arriving at an emergency call box. It is assumed that the individual that needs to make an emergency call is not precisely at the location of an emergency call box. This process time is a very important process when evaluating the effectiveness of using an emergency call box. Therefore, this study used three distance categories for the time it takes to arrive at an emergency call box within the

Purdue University, West Lafayette Engineering Mall area. Within the testing trials, times were evaluated using far, medium, and short distances from the closest emergency call box. Times were also evaluated when an individual is in continuous danger and may need to activate multiple call boxes as they continue escaping from danger. A maximum of two call boxes were allowed to be activated. The average arrival time to an emergency call box was 62 seconds.

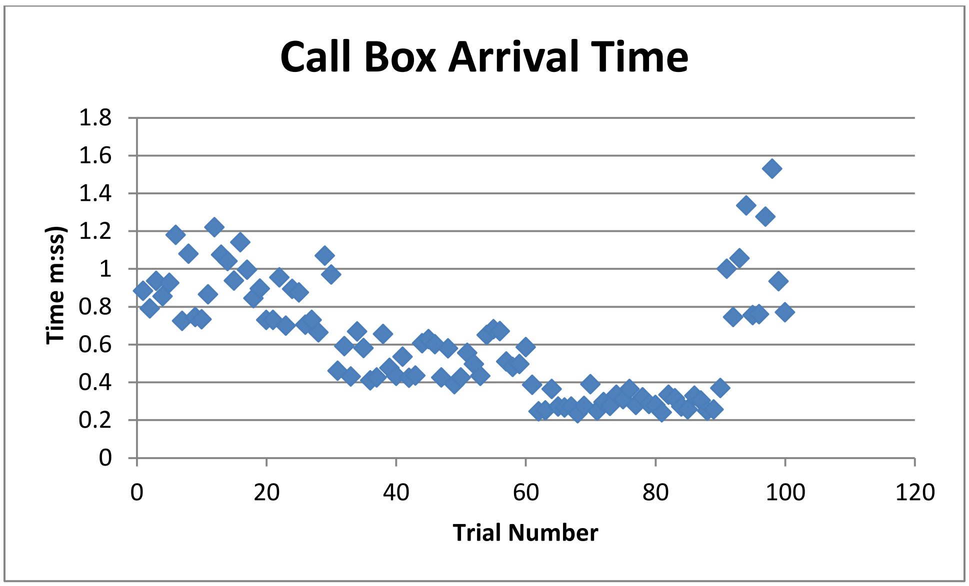

Figure 4.1. Call Box Arrival Time

4.3 <u>Effectiveness</u>

Assessing the call box effectiveness involved the time to arrive at a call box, the time between dialing for emergency and receiving a response, and the time between receiving a response and dispatching security. In the model, the time between dialing and receiving a response was added to the request for help process, making the request for help process a range between 25 and 45 seconds. The average overall effectiveness time was 1.21 minutes.

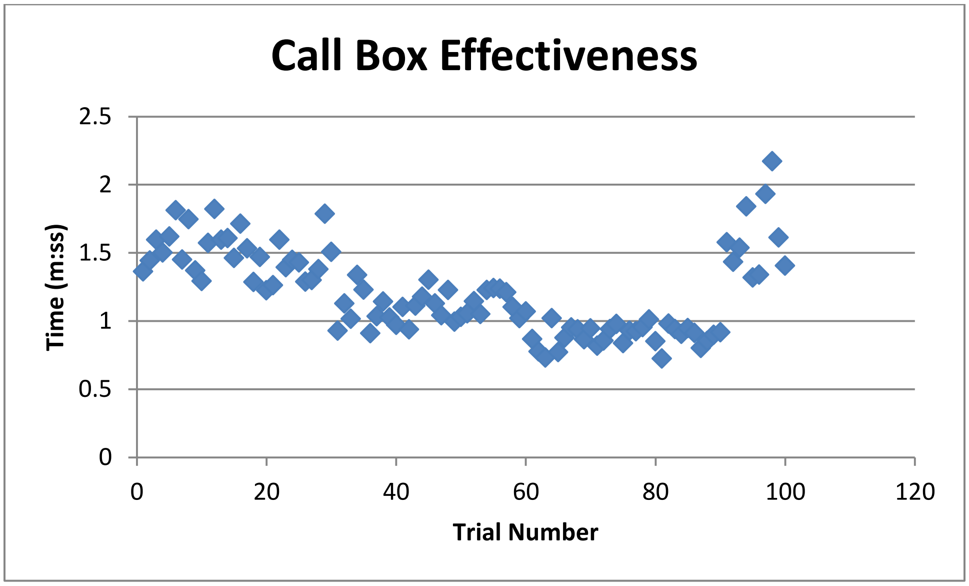

Figure 4.2. Call Box Effectiveness Time

The mobile safety system effectiveness includes time to dial and dispatcher response and the time between receiving the call and dispatching security. The model process involves an individual in the model traveling to a random safety area within the Engineering Mall and making the call. Therefore, the individual will still travel to safety area, but it was not a designated area. An estimated ten seconds was added to the mobile system request for help process in order to add time for dialing and receiving the dispatcher response. The average effectiveness time for the mobile safety system was 1.17 (mins.).

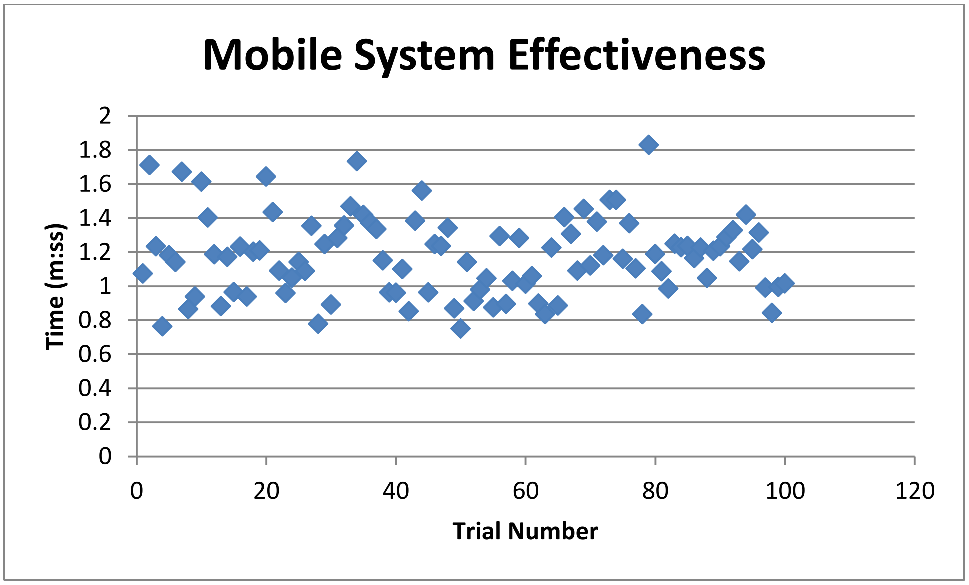

Figure 4.3. Mobile System Effectiveness

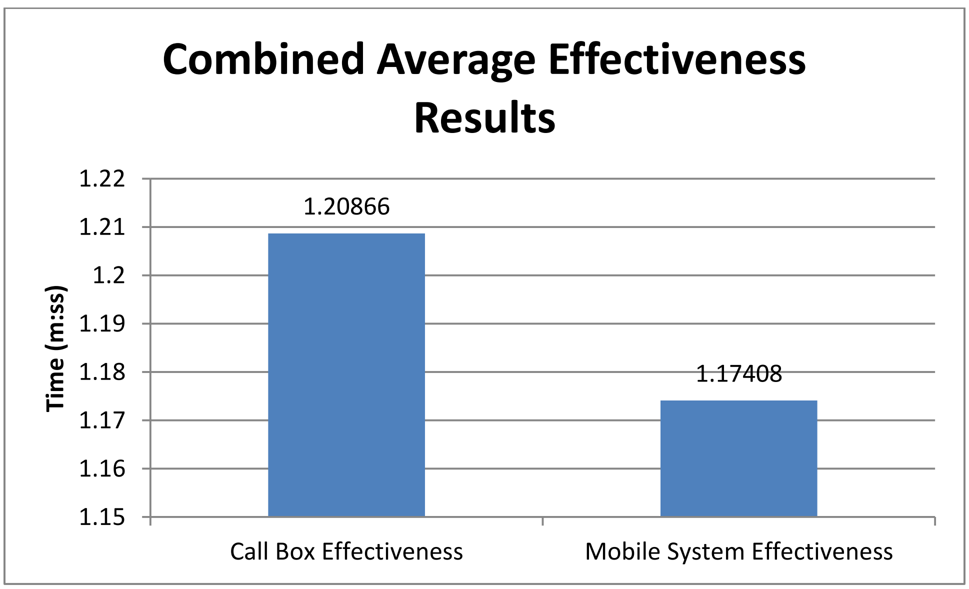

Figure 4.4. Combined Average Effectiveness Results

The distance away from a call box is a major factor for call box effectiveness. For long distances away from the closest call box, the average was 90 seconds. For medium distances, the average was 52 seconds. A short distance consisted of an average of 30 seconds. Finally, the need to activate multiple call boxes produced an average of 1.02 seconds.

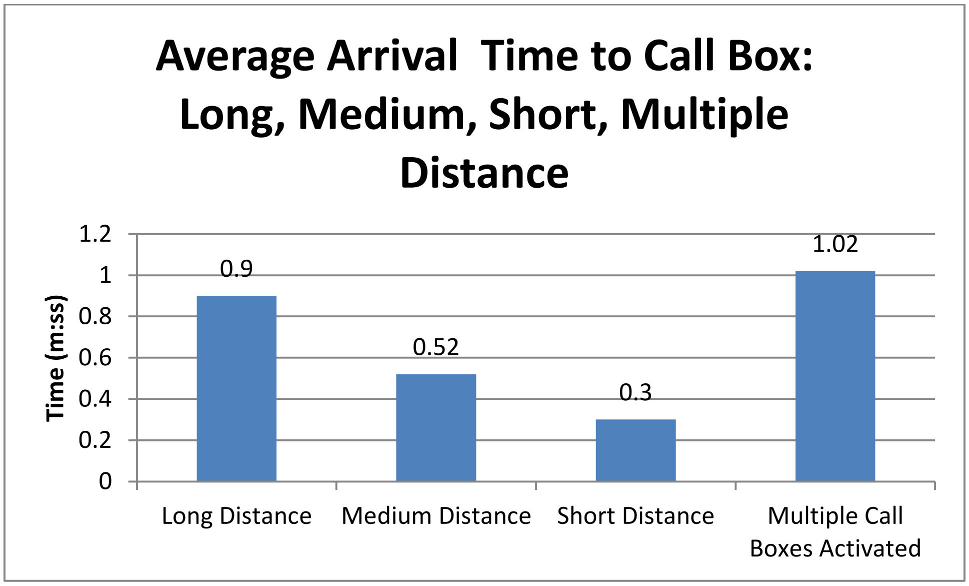

Figure 4.5. Average Arrival Time to Call Box: Long, Medium, Short, Multiple

The average effectiveness time for long distance was 1.5 minutes. The average effectiveness time for the medium distance was 1.1 minutes. For the short distance, the average effectiveness time was 89 seconds. Finally, the average effectiveness time for multiple call boxes activated was 1.61 minutes.

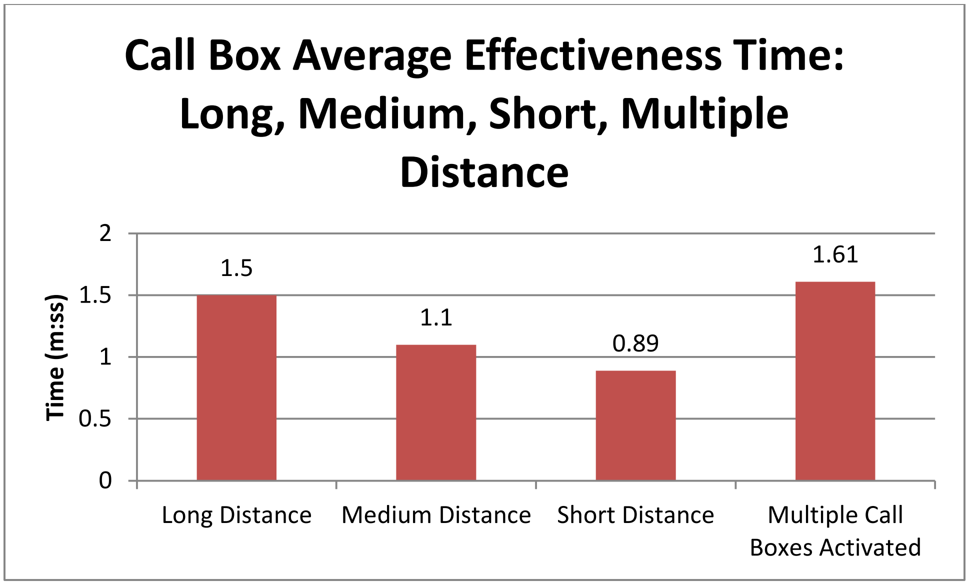

Figure 4.6. Call Box Average Effectiveness Time: Long, Medium, Short, Multiple

4.4 Response Times

The response time for an individual reporting an emergency using a call box involved the pedestrian relocating to a designated area close to the emergency call box. The average response time on the Purdue University campus is less than 2 minutes, and therefore a range of 60 – 240 seconds was used for the response time. The average time for response when an individual used an emergency call box for reporting was 3.76 minutes.

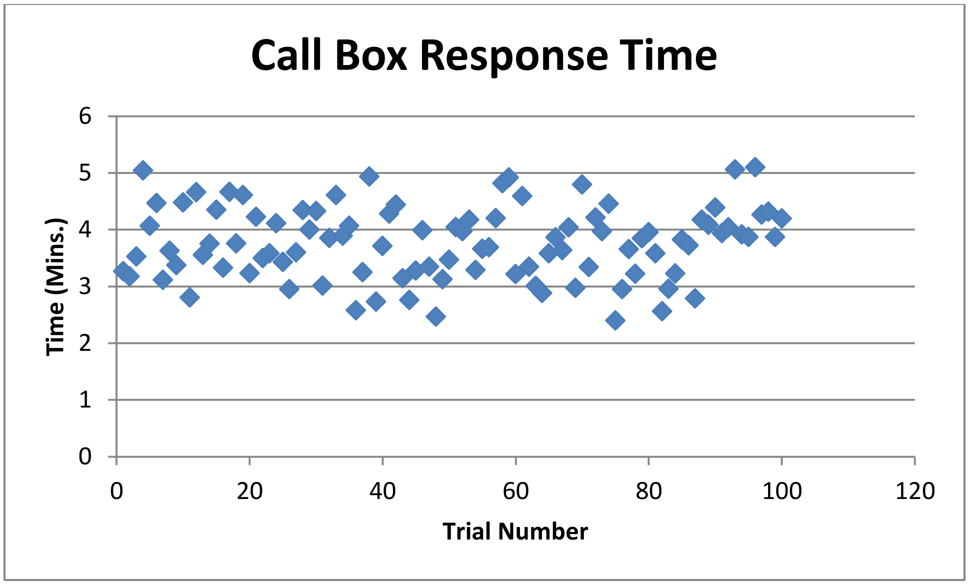

Figure 4.7. Call Box Response Time

The response time for an individual reporting an emergency using a mobile safety system included the pedestrian traveling to a random safety area within the Engineering Mall. The average response time using a mobile safety system was 3.98 minutes.

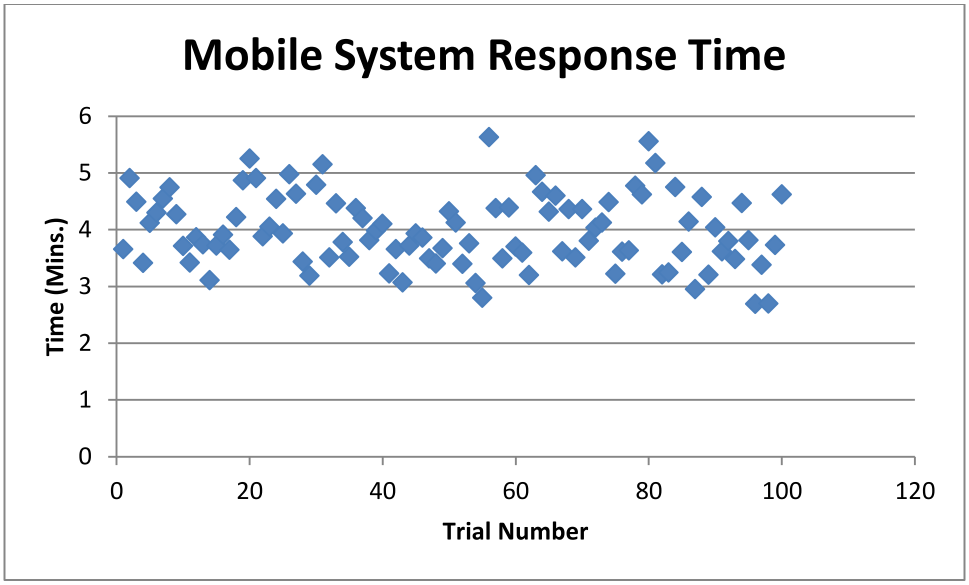

Figure 4.8. Mobile System Response Time

Figure 4.9 shows the combined results of the average call box arrival time, the average effectiveness times, and the average overall response times.

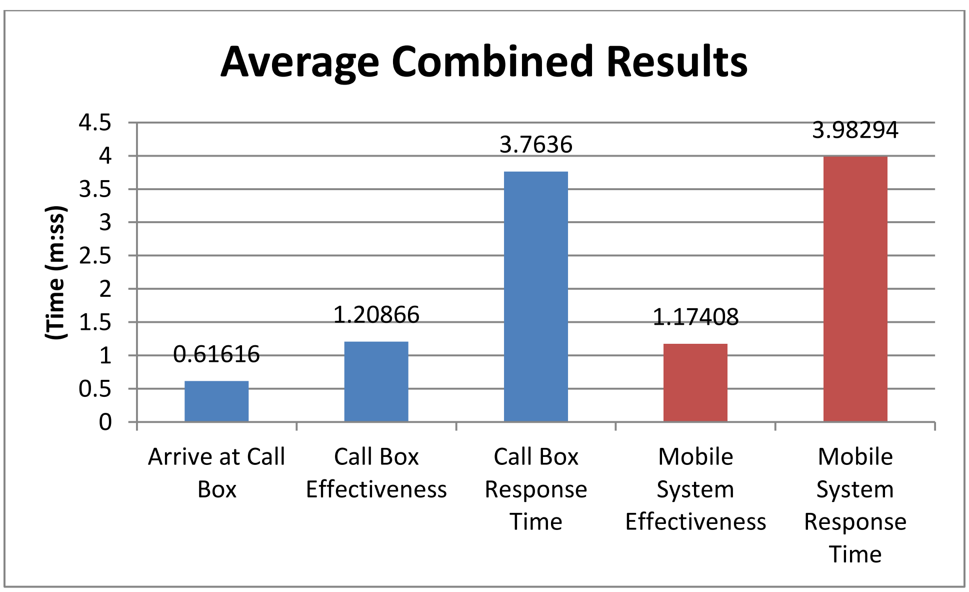

Figure 4.9. Average Combined Results

The average response time for the long distance category was 3.83 minutes. For the medium distance category, the average response time was 3.7 minutes. For the short distance category, the average response time was 3.6 minutes.

CHAPTER 5. CONCLUSION

Determining if a mobile safety system provides a faster overall response time when reporting an emergency depends on multiple sub-systems within the overall system. As the use of mobile devices becomes almost universal and the implementation of next-generation 911 becomes a reality, it is critically important for security chiefs to take advantage of mobile technology as it provides efficiency and lower costs in certain applications.

This case study assessed the overall response times and effectiveness when using an emergency call box versus a mobile safety system on the Purdue University's Engineering Mall area. Completing 200 trial runs, the study showed that the distance to arrive at an emergency call box is a key contributor to not being as effective. The mobile safety system involved more time to dial and getting a dispatcher response, however, it did not exceed the overall effectiveness of the emergency call box. However, with a shorter time to dial and receive a dispatcher response, the call box proved to have a faster response time.

The null hypothesis and both of the alternative hypotheses were tested for response times. The null hypothesis (H_{o1} Simulation modeling shows that using a mobile safety system for emergency calling and response does not change the response time when using an emergency call box) was determined to be false. This output was very unlikely, as a small difference in response time could be fatal in certain emergency scenarios. This was a positive result, as the goal of this research was to improve overall response time. This result was a good first step toward reaching the goal.

The first alternative hypothesis testing response time (H_{a1} Simulation modeling shows that using a mobile safety system for emergency calling and response provides a faster response time than using an emergency call box) was determined to be false. The results of the study showed that using mobile safety system had a slower response time. This was a negative result for the study, as the goal of the study assumed that using a mobile safety system provided a faster response time.

The second alternative hypothesis testing response time (H_{a2} Simulation modeling shows that using a mobile safety system for emergency calling and response provides a slower response time than using an emergency call box) was determined to be true. The results of the study showed the using a mobile safety system provided a slower response time. This was a negative result for the study, as it was assumed that the mobile safety system provided a faster response time.

The null and alternative hypotheses were tested for effectiveness. The null hypothesis (H_{o2} Simulation modeling shows that using a mobile safety solution has the same effectiveness for emergency calling and response as using an emergency call box) was determine to be false. This output was very unlikely.

This was a positive result, as the goal of this research to improve effectiveness. This was good first step in reaching that goal.

The first alternative hypothesis testing effectiveness (H_{a3} Simulation modeling shows that using a mobile safety solution is more effective for emergency calling and response than using an emergency call box) was determined to true. This was a positive result and goal of the research. The goal of this research was to improve overall effectiveness. The research showed that the mobile safety system is more effective than an emergency call box. The research also showed the arrival time to a call box greatly impacted its effectiveness in a negative way.

The second alternative hypothesis testing effectiveness (H_{a4} Simulation modeling shows that using a mobile safety solution is less effective for emergency calling and response than using an emergency call box) was determined to be false. This was a positive result of the study, as the goal of the research was to improve effectiveness.

The research showed that the average mobile safety system effectiveness time is more effective than the emergency call box; however, it has a slower average response time than using an emergency call box. Although not by much, the mobile safety system provided a more effective average time by 4 seconds. However, if an individual happens to be at a longer distance from the closest call box, the difference in effectiveness time was 33 seconds. For an individual who is continuously activating multiple call boxes, the difference in effectiveness time was 45 seconds. This shows that if an individual needs to continuously move in the area of the Purdue Engineering Mall and from long distances away from a call box, that it could result in a high number of seconds being lost for response.

The research showed that the mobile safety system provides a slower average response time than using an emergency call box. Arriving to a safety area when using a mobile safety system is random, in which an individual may need to only go a short distance to safety or it could be a longer distance to safety. As a result, the emergency call box provided an average faster response time by 22 seconds. Only if an individual activates multiple call boxes, does the mobile safety system provide a faster response time by 28 seconds.

The model can be used to assess emergency response times and effectiveness on different similar sized areas across a campus. Continued research should be done by allowing an individual to activate more than two call boxes in an area. In extreme conditions, it is possible an individual may need to escape to safety for a longer period of time. Therefore, activating more than two call boxes may be necessary. Also, with the discussion growth of next-generation 911, further research should be done assessing the effectiveness and response time when text messaging is used. Research has shown that messaging and other convenient methods that does not require calling, is being used more than ever. Therefore, adding other mobile services to this model should be completed for future research. Table 5.1 shows the hypotheses statement conclusions.

Table 5.1. Response Time Hypotheses Conclusions

Hypothesis Statement	True/False
H_{o1} • H_{o1} Simulation modeling shows that using a mobile safety system for emergency calling and response does not change the response time when using an emergency call box.	False
H_{a1} • H_{a1} Simulation modeling shows that using a mobile safety system for emergency calling and response provides a faster response time than using an emergency call box.	False
H_{a2} • H_{a2} Simulation modeling shows that using a mobile safety system for emergency calling and response provides a slower response time than using an emergency call box.	True

Table 5.2. Effectiveness Hypotheses Conclusions

Hypothesis Statement	True/False
H_{o2} • H_{o2} Simulation modeling shows that using a mobile safety solution has the same effectiveness time for emergency calling and response as using an emergency call box	False
H_{a3} • H_{a3} Simulation modeling shows that using a mobile safety solution is more effective for emergency calling and response than using an emergency call box.	True
H_{a4} • H_{a4} Simulation modeling shows that using a mobile safety solution is less effective for emergency calling and response than using an emergency call box.	False

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APPENDIX

APPENDIX. MODEL IMAGES

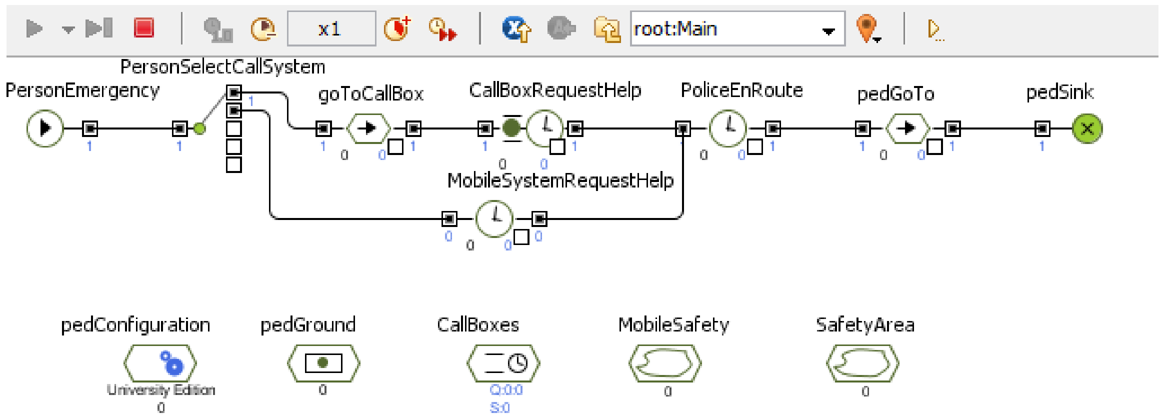

Figure A.1. Embedded Objects

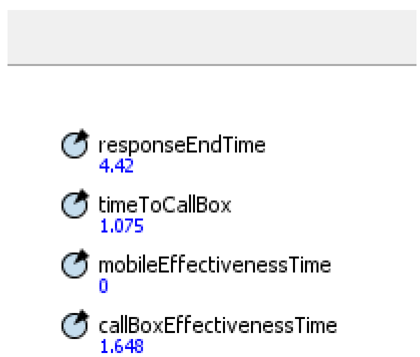

Figure A.2. Parameters

Figure A.3. 2D

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