ABSTRACT

ATKINSON, JEANNETTE M. Simulation of Search for Missing Child. (Under the direction of Dr. Julie Ivy).

The objective of this thesis is to develop a simulation-based approach for increasing the potential of finding a child in time to rescue him unharmed by varying the available resources. This computer model simulates the escape of an abductor with a child and the subsequent search for them. It is based on an actual event, and it is then compared to the simulation of a different approach to the search. The benefit of the additional approach to the simulation is the improvement in finding a missing child in time to rescue him unharmed. Once a significant improvement was found, then variations within this model were compared to find the most effective parameters.

For most of the population an abduction is a sad subject to consider, and even harder to research. There is no existing summary data, nor data available on specific abduction cases due to privacy issues. The researcher is left to research gruesome news in newspapers and magazine articles. Despite these limitations, we need to remember that children, as well as their abductors, are physical beings, and as such they are restricted by physical laws. Physical laws also encompass the evidence they leave behind, the abductor’s vehicle and home, and the geography of the area. It was therefore possible to develop a model by following physical laws such as that of distance, potential speeds, and potential traffic. The likely behavior of the abductor was based in part on common sense, such as his likelihood of not wanting to call attention by exceeding the speed limit. It is an enormous task, and therefore we hope many other researchers will continue to add more of their expertise to enhanced models.

In this thesis we simulate a search for a missing child from a specific school in order to increase the potential of rescuing the child unharmed. The geography plays an important role in these simulations. The different physical paths the abductor could take were simulated with a certain probability distribution assigned to each. Paths the abductor could take were simulated as a function of the areas with higher likelihood. For example, if there were more known sex offenders north of the current location, then the probability of the abductor going north was higher. If there were a large number of offenders living on a given road, then the probability of finding the child on that road is higher.

Having developed an extended model we were able to test the additional approaches to the model. This allowed us to see any improvement utilizing different resources. Some changes did not make any improvements. One of the most obvious first attempts was to increase the number of officers. This change did not show an improvement due to the following reasons. First, the number of homes of known offenders within the area is small compared to the total number. Therefore, the abductor is most likely outside the geographical boundary of the exercise. Also, it takes too long to search the individual homes and the run completes with few police searches. Much better visibility of the possible paths the abductor could take was needed. Some technologies considered were too futuristic, and quickly abandoned. Other technologies would be too expensive, and therefore unrealistic to implement.

Our research uncovered a number of existing technologies that can be combined and used. Some of these technologies are already in use for different purposes. Once a technology was found that could make a significant difference then it was tested with different parameters to compare the results. The most valuable realization was that the technology that proved to be the most beneficial is based on one that is currently the most cost effective. It is a technology that provides such excellent visibility that it has been accused of violating privacy rights. It is based on a common device that has been in existence for a long time, the photographic camera. The technology is the Red Light camera, and for the model we modified it to be a traffic-light camera that could be activated regardless of the color of the traffic light.

Once we had this ideal device we modified the model to find the most effective number and location of the cameras to allow the police to narrow their search. Our findings mean that even though it is very difficult to find a missing child, some changes can make a significant difference in finding a missing child in time to rescue him unharmed.

Simulation of Search for Missing Child

by
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DEDICATION

I dedicate this thesis primarily to my wonderful family. First, I dedicate it to my husband Paul, for his daily love, support and encouragement. Second, I dedicate it to my daughter Ruby for all her efforts to help me with my homework since she was only two years old. Next, I dedicate it to my parents and siblings for providing the motivation to endure during difficult times. And finally, to every missing child that is in desperate need of help from humanity.

BIOGRAPHY

Jeannette Atkinson received her undergraduate degree in Mathematical Science and Computer Science. She chose the graduate program in Operations Research at North Carolina State University because it was the best combination of these two fields. She quickly learned to appreciate the usefulness of this multidisciplinary field to provide humanitarian aid to those who are most helpless, and most in need: *missing children*.

ACKNOWLEDGMENTS

I would like to acknowledge my advisory committee for sharing all that wonderful knowledge of Math, Science, Engineering, and life in their teaching. It’s been an honor to have them as my professors and I am deeply grateful for their agreeing to serve in my committee. Dr. David Dickey is a wonderful and caring instructor who inspired me to join NC State. He is not only interested in our learning, but also in our well being; it is his example of kindness and humility that makes him such an exceptional human being.

I thank Dr. Stephen Roberts for the wealth of computer simulation information he shared with us in his class. His teachings definitely empowered several of us to start our theses or dissertations. All of a sudden something that seemed so out of reach became possible. He was always there to reply to our questions, and allowed us to choose the subject for our projects, which is where this thesis was born. It was also thanks to Dr. Roberts that I met Dr. Julie Ivy. Dr. Ivy's interest in humanitarian logistics and her willingness to help others is impressive and unique. She makes using math and engineering to help others a reality. I thank Dr. Ivy for her guidance, mentorship, and great advice.

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INTRODUCTION

Background

The overall objective of this thesis is to increase the potential of finding a child in time to rescue him unharmed by varying the available resources. It is a topic of primary importance to every community. Preventive measures have been put in place in a number of communities that have aided in recovering a kidnapped child quickly and safely. This thesis compares the statistical difference between a system without preventive measures and a system with the added measures.

The need for improved searches for missing children is evident in the number of unsolved cases. Along with this, communities are faced with hundreds of known sex offenders. The United States Department of Justice indicates that Wake County alone has 563 offenders (The United, n.d.). The Office of Juvenile Justice and Delinquency Prevention (OJJDP) published the following message in its June 2000 bulletin: "The kidnapping of a child is a crime that tears at the fabric of society." This is an excellent description of the damage caused by such acts. And, to the best of our knowledge there is little research on the search for missing children.

The National Center for Missing and Exploited Children currently lists 48 Children missing in North Carolina. This count is based on a lookup of the *Missing Kids for North Carolina, USA* (2010). The recent incident, when a first grade child went missing from Yates Mill Elementary School (Capitol Broadcasting Company, 2007), and many other news of missing children have led me to realize that there is a significant need for the analysis of recovery tools. A simulation of the different methods can help convince influential individuals of the need for the improvement(s). In contrast, an analytical approach may never even be read, or understood.

There is computer-aided search management software in Ireland as indicated in the document *Live Asset Tracking and Statistical Modelling in Missing Person Search* (n.d.). It is a model developed to help in the search for a missing person, but not one that has been abducted. It uses a "Lost Person Behaviour Profile" to estimate movement. The search individuals carry GPS tracking devices to allow a visualization of their movement. It is especially helpful in rough mountainous terrain where a search party would have difficulty knowing what directions to take. This aide could be helpful in the foot search of the child in the neighboring parks. It would however need extra time, specialized equipment, and volunteers. Once the police are certain that the abductor has taken the child to such an area, then this aide would be useful.

There are several examples where technology has already helped to find a missing child. The two most familiar systems are the Emergency Notification System and the Amber Alert system. One of the most direct examples of the Emergency Notification System can be seen in the YouTube video *Missing Child Recovered in 20 Minutes Using Emergency Notification System* (2009): "In September 2006, the Frankfort, Kentucky Emergency Management Agency performed a GIS-mapping alert with Twenty First Century Communications' (TFCC) emergency notification system. They asked residents within a certain radius to call 9-1-1 if they spotted a missing child. Citizens responded and the child was safely recovered within 20 minutes of the alert." Safe recoveries of missing children are still rare, and this thesis will demonstrate that other technological advances can be very helpful when utilized in the search for missing children.

Problem Definition

This thesis develops a simulation of a hypothetical kidnapping and the resulting search in order to increase the potential of rescuing the child unharmed by varying the available resources. We develop two simulation models of a search for a missing child from a specific school. One model replicates the event with existing available resources. A second model incorporates controlled measures for increasing the chance of locating the child as quickly as possible. The models are based on the event of the October, 2007 Missing First Grader incident at Yates Mill Elementary School in which the child was picked up in front of the school by a motorist and driven several miles away to a building in downtown Raleigh. This incident is described in the article, *Wake First Grader Leaves School* by the Capitol Broadcasting Company (2007).

These simulations are equivalent to practicing an escape route in emergency evacuations. When a child is abducted, it is essential to promptly start a very organized search to increase the potential of rescuing the child unharmed. A physical simulation of such an event is costly to a community, but a computer simulation can serve the purpose without these negative effects. Accounting for existing facts about a community, such as geographic information on concealed areas, can help prepare the community for a needed fast and accurate search.

A detailed geographical model is critical to simulate the decisions an abductor would make at every intersection of the roads. If there is a larger number of known sex offenders living in a given area, then the probability of the abductor traveling in that direction is higher.

Therefore, the probability of finding the child on the roads in that direction is also higher. This model incorporates the geographic location of the kidnapping and the location of high probability areas in order to identify the most effective search strategies.

Figures 1 and 2 are maps provided online by the North Carolina Department of Justice show the location of the known sex offenders' homes in the city of Raleigh. These maps display the locations of known sex offenders within a radius in the selected area with three choices for the radius: one, three, and five miles. A startling realization is that there are 80 offenders within a five miles radius of the Yates Mill elementary school, which is at the center of this research. Even if we had 80 volunteers instantly available, it would be impossible to get them to the right locations in time. Therefore, it is essential to be able to focus the search in the most appropriate directions.

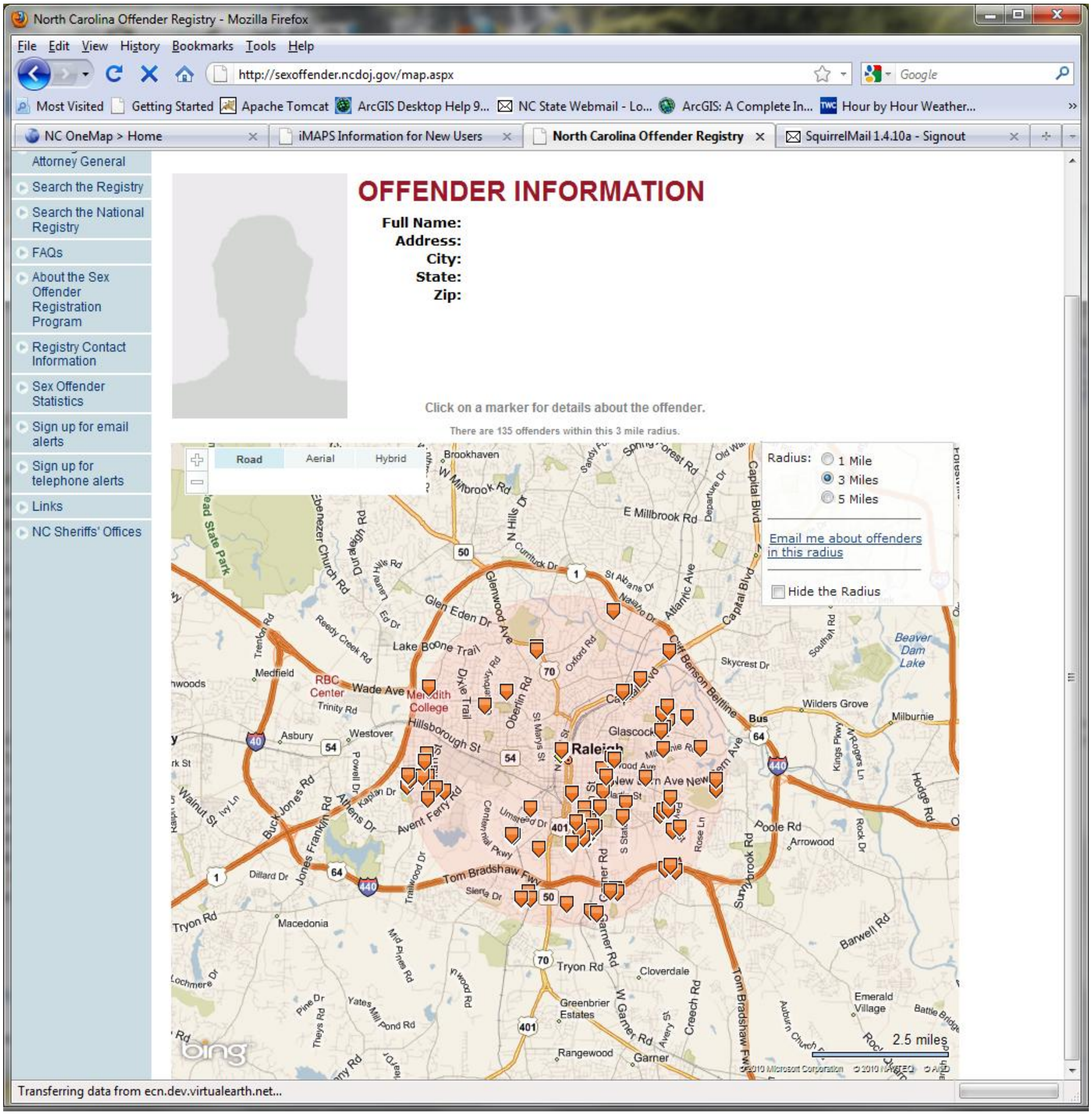


Figure 1. Offender information – Raleigh, from http://sexoffender.ncdoj.gov. This map uses the center point of the city of Raleigh, which is at latitude 35.7853, and longitude -78.6435.

Figure 2 enlarges the area better to see more detailed mapping and is centered at the Yates Mill Elementary school. In this map we can see that the count of the sex offender locations in the northern direction from the school is higher than the count in the southern direction. This indicates that the offender is more likely to travel north than he is to travel south if it is a sex offender living in the area who intends to hide the child in his home. Other areas of high probability, such as concealed areas, will also affect the overall probability of the kidnapper traveling in that direction.

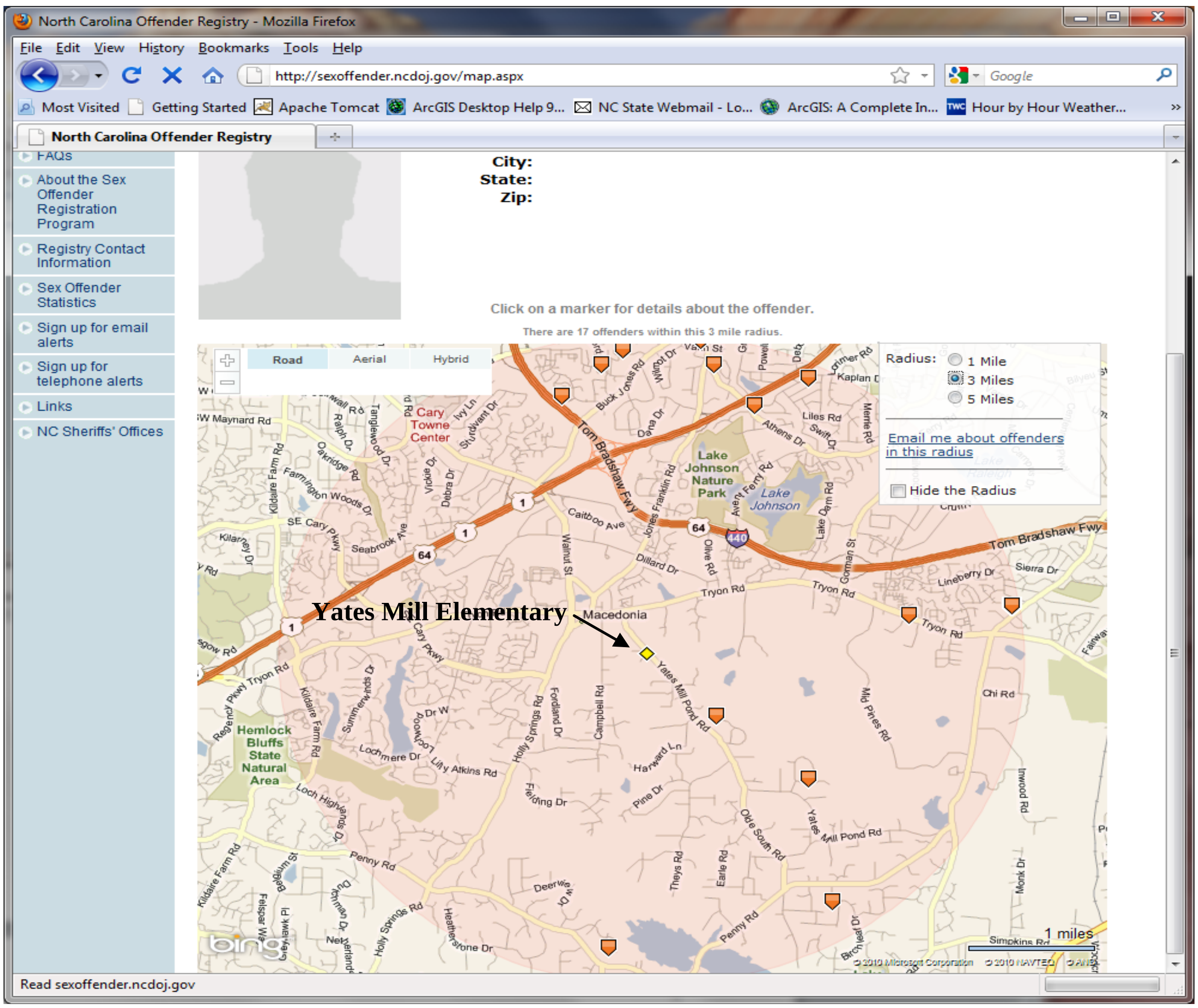


Figure 2. Offender information using a three mile radius– Yates Mill Elementary (zoom), from http://sexoffender.ncdoj.gov. This map uses the center point of the Yates Mill Elementary school, which is at latitude 35.739686, and longitude -78.729138 using a three mile radius.

The geography and demographics presented above allow for a significant improvement over the original computer simulation model of the Search for a Missing Child. The image of the higher radius shows the concentration of offender locations, and it is used to influence the probabilities at the decision points based on the counts towards these locations. The map that focuses on the one mile radius is displayed on the actual simulation model.

Statement of Scope and Objectives

This computer simulation of a Search for a Missing Child is based on the actual event of the Missing First Grader incident at Yates Mill Elementary School in which the child was picked up in front of the school by a motorist. The original model is built to match the event and a second simulation model is created with a different approach to the search and is compared to the original simulation model. In the model it is also assumed it is the middle of the morning on a school day. This assumption is needed in order to assign a distribution to the arrival of other vehicles in the model.

This simulation allows for abductions by family or strangers. It is, however, limited to vehicle-based abductions. The starting location of the abduction simulation is Yates Mill Elementary School. The scope of the escape and the search in the model includes all of the following roads: Yates Mill Rd., Tryon Rd. between Dillard and Jones Franklin Rds., Old South Rd., and Penny Rd. between Lake Wheeler Rd. and Spring Forest Rd. Further, it is assumed that the present system has only three police officers available at the time of the event. The school and the boundary roads are emphasized in Figure 3 for clarity.

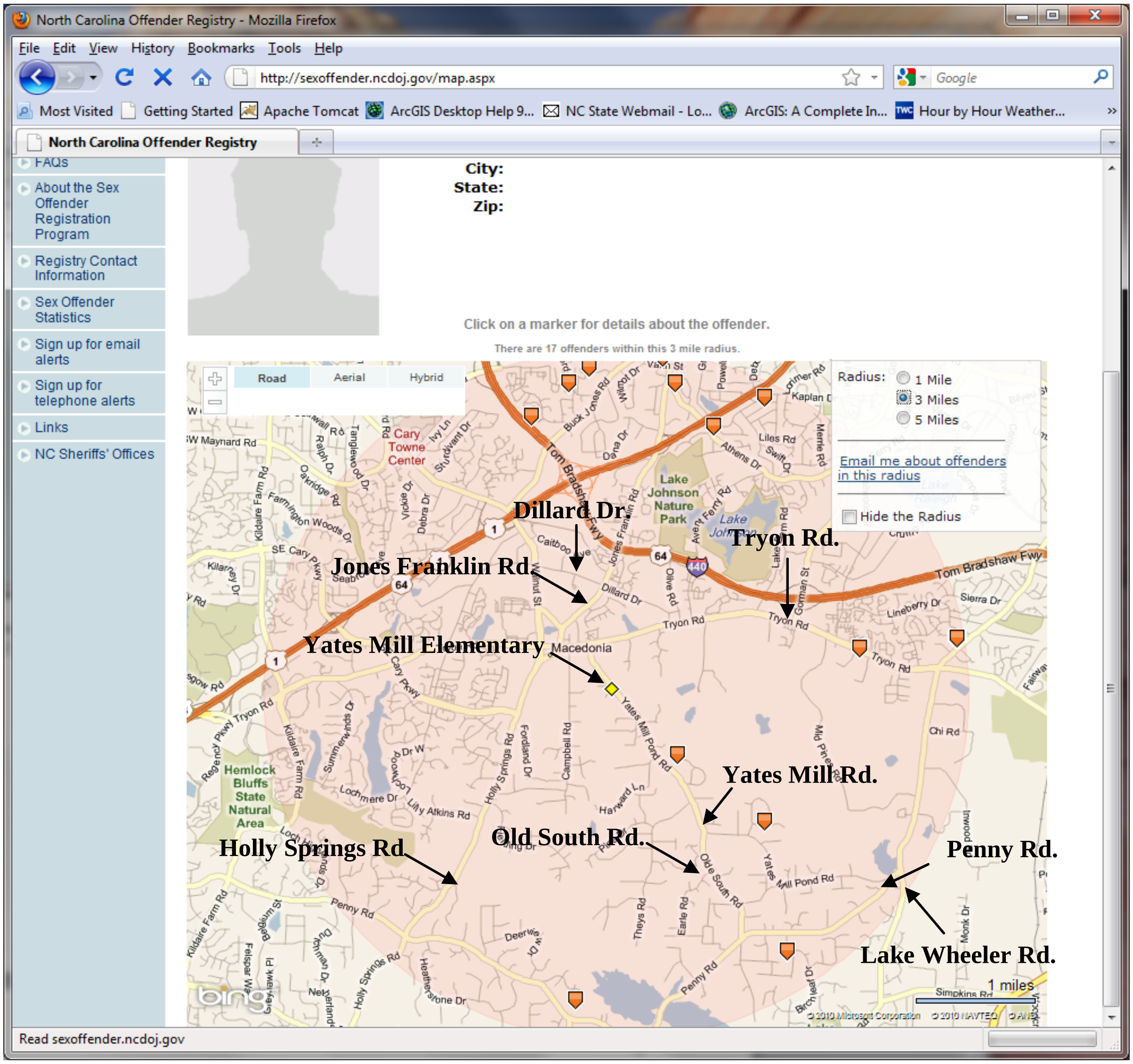


Figure 3. Simulation road boundaries. This map uses the center point of the Yates Mill Elementary school, which is at latitude 35.739686, and longitude -78.729138 using a five mile radius.

The model has been improved with the resources that provided the best results. The search is based on which of the different types of aides, how many of each, and at what locations, generate better results in finding a child. The different types of aides are listed in the section: "Potential Aide Entities and Resources."

The number and location of each different type of aide that would be sufficient to increase the probability of finding the child within a time limit has to demonstrate a significant difference. The time limit is very important because the longer the time elapses after the abduction of the child, the harder it is to find the child, and the lower the probability that the child will be found unharmed.

METHODS

Model Construction

The simulation models consist of the escape by the abductor with the child in a vehicle from Yates Mill Elementary School. The original model consists of the original event and a second simulation model is created with a different approach to the search and compared to the original simulation model. Both models have empirical distributions developed to simulate the flow.

Since abductions do not follow a specific pattern, we made a number of assumptions and estimates for the probability distributions. For example, the lack of a security guard at a park would make it a more likely hiding place for the abductor than a secured park. Physical laws of distance, potential speeds, and potential traffic were estimated. Also, the likely behavior of the abductor was based on common sense. For example, an abductor would not want to call attention, and would therefore attempt to follow the speed limit. He is also going to be more likely to take the child to a park that has easy access to concealed areas, than one that is very public.

The model grows in complexity quickly as the number of intersections increases.

There is greater uncertainty as each minute goes by. An additional challenge is that there is erratic behavior of individuals. Human beings, especially when in escape mode, do not follow exact patterns as can be expected when modeling machinery. Individuals can drive faster, or slower, than the speed limit, or they may need to stop frequently due to a school bus, thereby increasing the variability in the model. We attempted to incorporate as much as familiarity with the area allowed in order to increase the accuracy of the simulation.

This thesis compares the statistical difference between the system without preventive measures to a system with the added measures. One section of the model consists of the search for the abductor/child by the police. The length of the replication was entered as a variable and tested with different values. The final value we used for the calculations was a replication length of 20 minutes.

The map in Figure 4 uses the center point of the Yates Mill Elementary school, which we can identify by the yellow diamond.

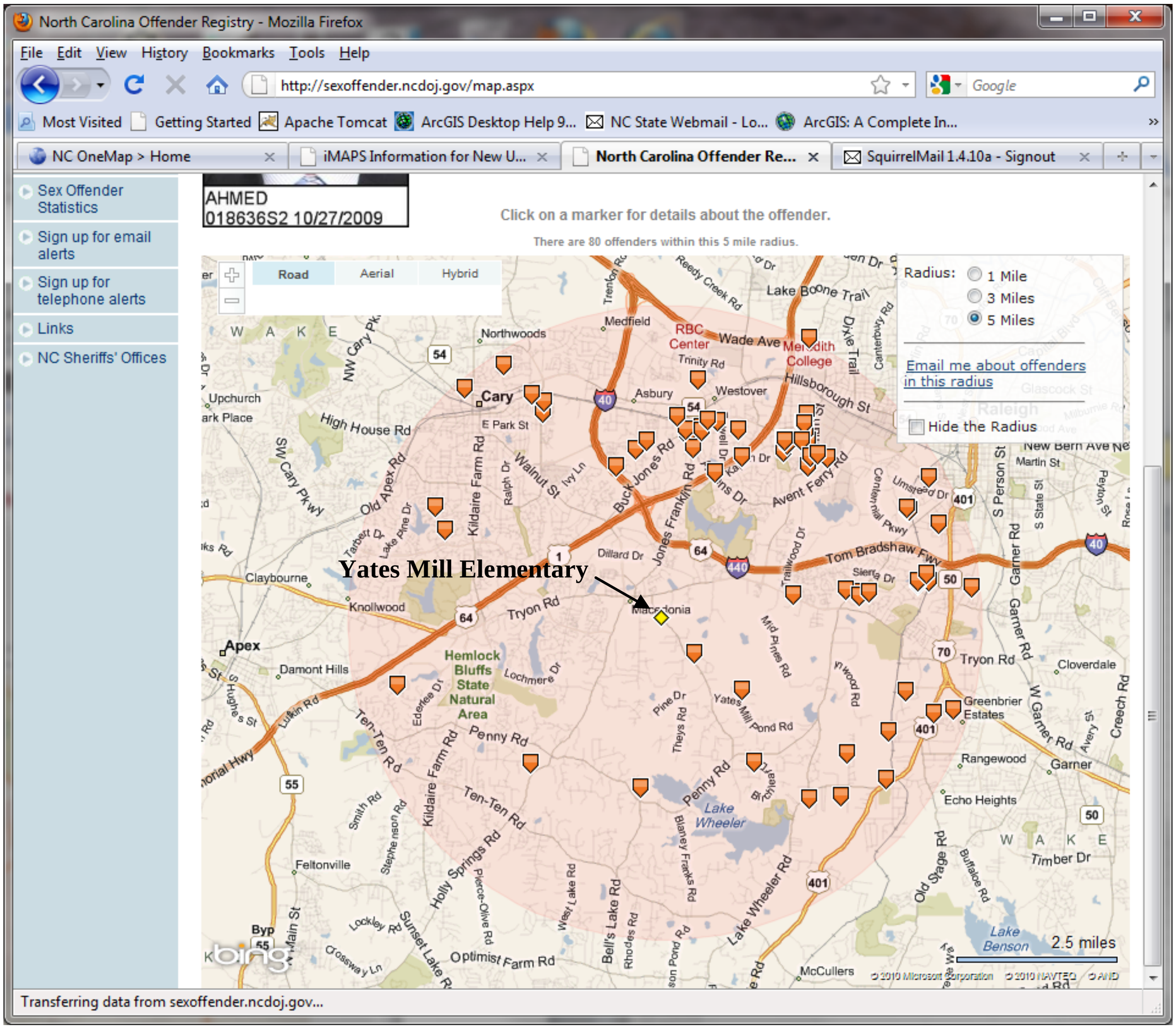


Figure 4. Offender information – Yates Mill Elementary, from http://sexoffender.ncdoj.gov. This map uses the center point of the Yates Mill Elementary school, which is at latitude 35.739686, and longitude -78.729138 using a five mile radius.

There are 80 known sex offenders within a five miles radius of the Yates Mill elementary school as we can see in Figure 4. We can also see the possible directions the abductor can take when he drives off with the child from Yates Mill Elementary School. In the model the abductor decides which direction to take on Yates Mill Road. Each intersection of the road requires a decision on which direction to take, or to stay within one of the houses on the specific road. The time to reach each intersection on the road has a specific distribution which is directly proportional to the distance and the speed limit of the road. This time is specified in the “Delay” blocks in the simulation. Once the abductor has hidden within the specified road, or has reached one of the boundaries of the exercise then the entity has reached its final step within the model, and it is removed with the Arena block named “Dispose” which is labeled “Hidden or Out of Range.”

In this section we have introduced the steps taken in the construction of the model. In the following section we will see flowcharts that facilitate the comprehension of the system.

Flowchart and Model Preview

The flowcharts included in this section display the flow that is used in the computer simulation models. The first one is based on the original incident. The second one uses all the potential intersections in the road that the abductor can take during the limited time of the simulation.

The following is a list of events that take place in the base abduction model, and it can be appreciated better in the flowchart that follows it:

1. Abductor arrives.
2. Abductor drives off with child from School and Witness calls 9-1-1.
3. The Abductor decides Which Direction to take, North, South or stay Within school area.
4. Abductor meets the Traffic Light at the Yates-Mill Rd. and Tryon Road Intersection.
5. The Abductor decides Which Direction to take, East or West or Within.

6. Abductor meets the Dillard Drive Traffic Light.

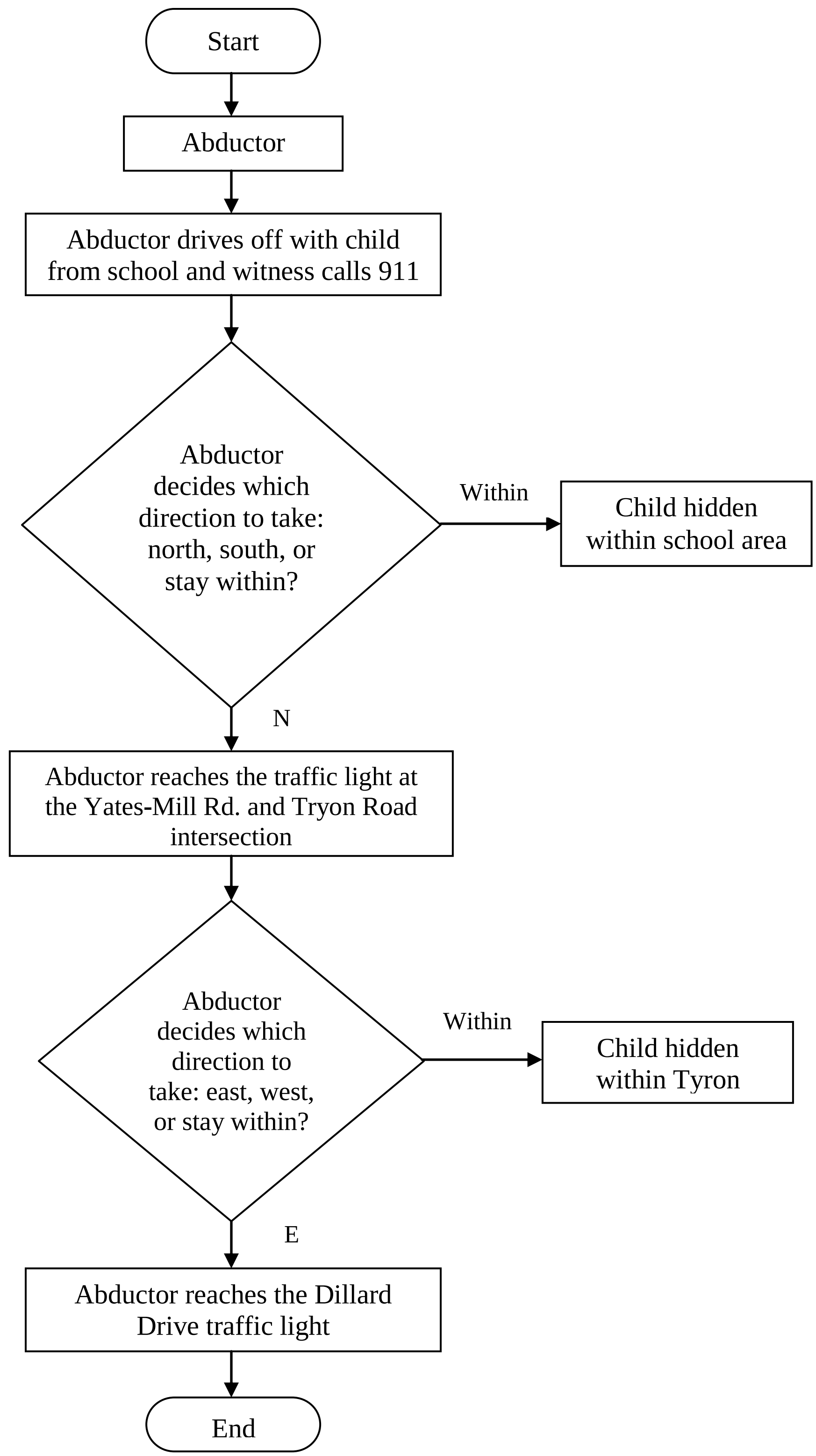


Figure 5. Original incident – base abduction flowchart.

The flowchart in Figure 5 facilitates the reading of the base abduction Arena model of the original incident as depicted in the Figure 6:

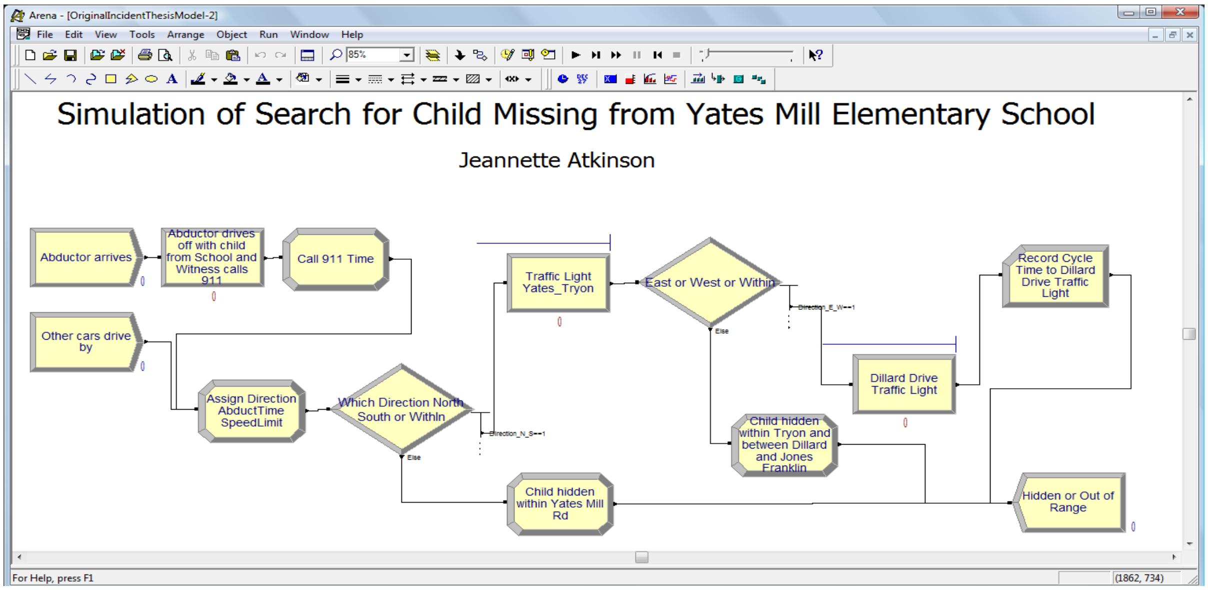


Figure 6. Original incident - base abduction Arena model.

In this section of the model, we can see the beginning steps to building the extended model. It is based on the small set of decisions given the path taken by the conductor who took the child on the original case.

I. Abductor drives off with child from School and witness calls 911.

IA. Abductor decides which direction: north, south or stay within the closest intersections.

IA-1. Abductor reaches Yates_Tryon traffic light.

IA-1.1 Abductor decides which direction: east, west, or stay within the closest intersections.

IA-1.1.1 Abductor reaches Dillard Dr. traffic light.

IA-1.1.2 Child is hidden within Tryon Rd. or between Dillard Dr. and Jones Franklin Rd.

IA-2. Child is hidden within Yates Mill Rd.

In the previous flowchart and model, we saw the paths and decisions of the escape of the abductor. In the flowchart in Figure 7, we will see the different decision processes of the police or volunteers:

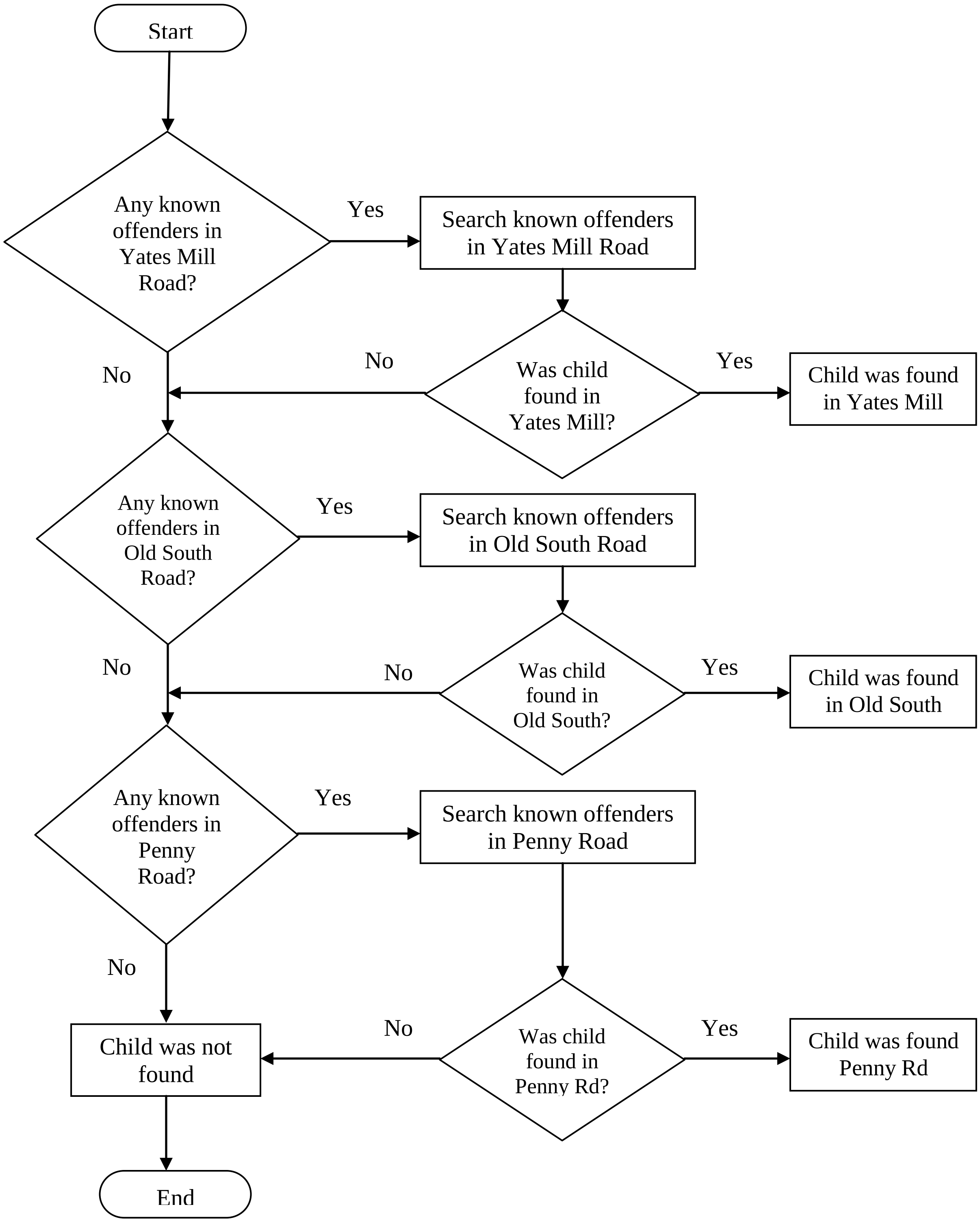


Figure 7. Original incident – search by human aides flowchart model.

In the flowchart in Figure 7 we can appreciate the search performed by the police officers or volunteers, and we will see it again within the Arena model itself in Figure 8.

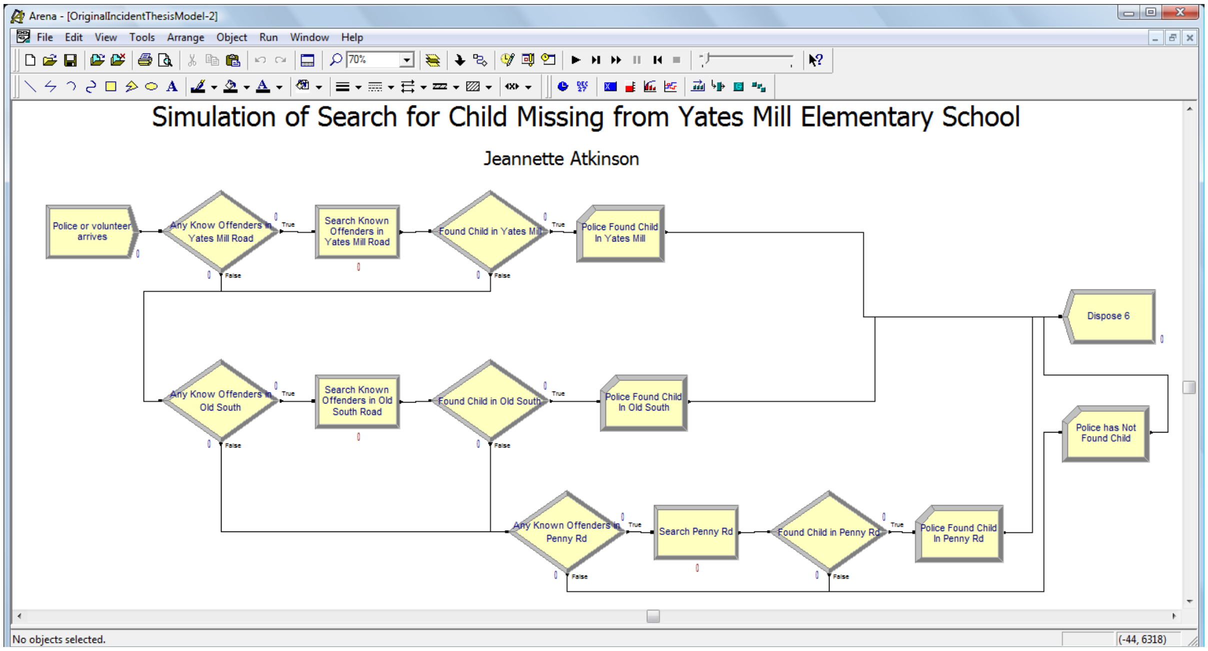


Figure 8. Original incident – search simulation Arena model of Police/Volunteer Decision Process.

In Figure 8 we can see the continued need of the human aides for a complete search. Even though it is impossible for officers to appear instantly at the scene of a crime, they are still essential given the small, but yet existing probability that the abductor could be in the neighborhood. The abductor could have hidden the child in his home already, and if he is already a known sex offender then an officer can search the home without a warrant since a previous sentence as sex offender is already probable evidence. The officer's flow through the model is based on the knowledge of the location of the homes of past sex offenders as follows:

I. Officer arrives and decides which direction to go based on the knowledge of the location of sex offenders on Yates Mill Road. If there are any sex offenders within Yates Mill Road, then the officer proceeds to the following search process before going to the next closest intersection.

IA. Officer searches known offenders on, or adjunct to Yates Mill Rd.

IA-1. The next decision on behavior is based on whether the officer found the child. If he found the child then the model updates the statistics and the case in the model goes to the dispose block. Otherwise he goes to the next decision block.

IA- 2. If there are any known sex offenders on Old South Rd., then he proceeds to search their homes.

IA-2.1 If the Officer found the child while searching known offenders on Old South Rd. then the model updates the statistics and the case in the model goes to the dispose block. Otherwise the officer goes to the next decision block.

IA-2.2 If there are any sex offenders within Penny Rd., then the officer proceeds to the following search process.

IA-2.2.1 The Officer searches known offenders on, or adjunct to Penny Road.

IA-2.2.2 The next decision on behavior is based on whether the officer found the child. If he found the child then the model updates the statistics and the case in the model goes to the dispose block. Otherwise the model updates the statistics to indicate that the officer has not found the child and the case in the model reaches its limit and goes to the dispose block.

In this section, we have detailed the specific steps taken as the basic flow for the model. In the following section, we will introduce the characters and items that play a part in the system.

Simulation Model

The simulation model contains the entities, the resources, the processes, the queues, and the variables. The simulation model has a top section that represents the escape, and a bottom section that represents a police search. The top section is depicted in Figure 6 - Original incident - base abduction Arena model. The bottom section is depicted in Figure 8 - Original incident – search simulation Arena model. The new term used that needs to be clarified is a traffic-light camera, which differs from a red-light camera in that it takes the picture at the time a vehicle crosses the traffic-light, regardless of the color of the light (green, yellow, or red).

The entities are the images we see which flow through the model. The entities include the vehicle that contains the child and the abductor, the cars of the police officers, and other cars. Other cars cause more delays at traffic lights and also generate more confusion for searchers, but these may also be good witnesses.

The resources do the work on the entities, or as the entities drive by. In our models the resources are the witness, the police officers, and the roadblock aides at each intersection.

The processes involve actions such as delays, and seizing and releasing of resources. In our model the processes are the traffic lights with their specified delays and roadblocks. The other process is the search on the bottom portion of the model as depicted in figure 12.

The queues are the traffic light/roadblock queue and the search queue.

The variables are used to keep important information, such as distances, the extra time required when it is a left turn, and as flags. The roadblock “Variable” is used in two different ways: as a roadblock or as a traffic-light camera. If instead of a roadblock, there is a traffic-light camera at the intersections surrounding the school, then the roadblock will have a search time of zero.

As is already the case with some existing red-light cameras, the traffic-light camera could photograph the driver’s side image and the license plate. The existing default is for the red-light cameras to trigger when a vehicle runs a red light, but the cameras may be modified to trigger with green or yellow lights as well. These photographic cameras would collect the information necessary to narrow the search. In the cases when there is already a description of the abductor’s vehicle, an operator aide receiving the information from the cameras can direct the search in the right direction. It saves time for the search aides to direct their search to locations in the same direction as the abductor. In the cases when there is no description of the abductor’s vehicle, the police can follow and search those who were photographed exiting the area during the corresponding period of time. Also, by using the license plate recorded, the police can narrow their search.

Potential aide entities and resources. The type of aide that helps with the search can vary significantly, in both quantity and types of benefits. Some of the aides can be thought of as entities (such as the volunteers), and some can be thought of as resources (such as the individuals responding to the *Emergency Notification System*). Some of the following ideas for subsequent trials would provide much better results than others, but they may have higher delays, or their cost may be greater.

Roadblocks by officers or volunteers can increase the probability of finding the child proportionally to the number of roads that can be blocked, the "weight" of the roads that are blocked, and the number of vehicles that are blocked. The "weight" of the roads that are blocked is assigned according to the number and size of the high probability locations in that direction. These high probability locations are empty buildings, parks (such as Lake Wheeler Park), and homes of sex offenders. Queues build up at these roadblocks and any balkers are highly suspicious. The roadblock is a variable with a unique name per intersection on the road. If it is it set to zero, then the delays do not have any time added. If it is set to one then each intersection on the road will have a delay proportional to the number of cars times the time to search a car, which will be defined in the variable labeled CAR_SEARCH_TIME. The police officer(s) and the aides need to set up immediate coverage of highly dangerous areas where the subject can quickly hide the victim, such as the dump on Yates Mill Rd. and Lake Wheeler with its easy park entrance. The entrance has no guard, and it has many unpopulated access points to the lake.

The Emergency Notification System (TFCC1, 2009) increases the chance of finding the missing child proportionally to the number of households that have a person available to listen to the phone and to look out the window. This system involves calls to the houses in the area alerting them to the escape and requesting their attention just like the Amber Alert system. Such systems can be very effective, such as the one recently installed in the neighboring city of Durham as explained in the article *Durham City Government has instituted the CodeRED® Emergency Notification System - an ultra high-speed telephone communication service for emergency notifications* (n.d.). The system is capable of dialing up to 1,000 phone numbers per minute. It then delivers a recorded message to either a live person or an answering machine.

The Emergency Notification System can be enhanced to suggest the use of still or video cameras to photograph or record any vehicles driving by, and to email the images to a central location for analysis. This would increase the probability of eventually finding the child by the number of clear photographs that the police can collect, but not in time for the length of this simulation.

Extending the notification system to include calls to cell phones increases the chance of finding the missing child proportionally to the number cell phone holders in the area. Also, the cell phones holders in the area may have better visibility of the moving vehicle in question and are good potential witnesses. They could use their cameras, if available to photograph the vehicle in front of them. The focus on the target can be accomplished by using the same triangulation technology that is currently used in 9-1-1 calls, where the *call sector* is the perimeter served by specific cellular antennae, and triangulation "refers to the alpha, beta or gamma portion of the antennae from which cellular calls are received and transmitted" (AT&T, 1997). Even if the abductor does not have a cell phone, potentially other individuals contacted may have observed him/her. Contacting these individuals can generate a clearer picture of the population at the time and location of the event. We built a model of this system, but abandoned it due to the safety concern for the drivers. Also a new law is now in effect to prevent drivers from texting, and in some states it is also in effect for any cell phone use while driving. The last thing we want is to cause an accident that would distract the attention of the police from the case. The use of cell phones as aides in these situations is also not a profitable idea, and it would be very difficult to obtain help from the cell phone companies to locate the drivers in the area. The model had already been built therefore it is attached in Appendix D.

The use of Pictometry has a significant impact in increasing the probability of finding a child. This 3D-like aerial image system was just implemented in the neighboring city of Durham where it allows officers responding to 9-1-1 calls from the Emergency Communications Center to see the area around the inbound caller's location in a detailed and precise map (City of Durham, 2010).

Following, searching, and interrogating the moving cell phone holders in the area increases the probability of finding the child by a rate proportional to the number of vehicles searched. GPS software is capable of tracking a caller's exact location, but if GPS is not activated, the software will use triangulation based on cell tower information to identify the area where the phone is located (The Technology, 2010).

Human aides such as additional police officers or volunteers can increase the probability of finding the child by a rate proportional to their number and proximity to the abductor. These individuals can be notified as part of the instant Emergency Notification System. They can use their computers or phones to agree on the closest locations to search. These aides can be scheduled to go to specific areas that are already near them. The areas searched first should be empty houses or buildings, concealed areas near a lake, pond, or stream, and houses or apartment buildings inhabited by prior sex offenders. One drawback to this, compared to the notification systems, is that the time required to get the aide to the area is longer than the time the abductor needs to escape, or to hide the child. A second drawback to the help of human aides is that they cannot enforce the entrance to search a house or car without the proper warrant. They can at least provide a list of those who do not volunteer to cooperate to the police and help narrow the areas that the officers have to search with specific warrants. A third drawback to this idea is the safety of the aide.

A traffic-light camera at the intersections would help collect the information necessary to narrow the search. In the cases when there is already a description of the abductor's vehicle, an operator aide receiving the video information can direct the search in the right direction. It saves time for the search aides to direct their search to locations in the same direction as that of the abductor. In the model, this camera and its operator would have the same effect as a witness. In the cases when there is no description of the abductor's vehicle, the police can follow and search those who were photographed exiting the area during the corresponding period of time. And, by using the license plates, the police can search their vehicles, and ask to search their homes.

Automated License Plate Readers (ALRP), such as the ones purchased by the city of Raleigh, are currently installed on the front of patrol vehicles, and are able to photograph license plates of vehicles as the patrol officer rides around an area. The system sends images to a central location where the images are processed to interpret the letters and numbers on the license plate. Once the image recognition system identifies the plate, along with the color of the vehicle, the system then searches for the number in a database and feeds any helpful information to the patrol vehicle. The officer in the vehicle can then confirm the license plate information, and proceed to stop the vehicle in question. This system is already proven to help in various situations. The help in a search for a child is proportional to the number of patrol vehicles available in the area at the time of the occurrence. It is even better if various neighborhood vehicles volunteer to have this system added to their autos. A patrol could be any person in the neighborhood, or area. Delivery vehicles are good sources of information, as well as mail trucks.

The traffic-light cameras can be upgraded, and these images could be processed in an image recognition program similar to the one listed above. The images provide information on color and make of vehicles, and perhaps a glance at the number of persons in a vehicle. The quality of the image provided by the cameras is important, but it does not need to be a deterrent to the use of affordable cameras. The amount of help this system can provide is proportional to the number of cameras available, and to the quality of cameras.

Dogs held by a responsible human aide, especially if already trained by police, can be used to help search for the child. Their great sense of smell can increase the probability of finding the child proportionally to the number used times two. The drawback to this, compared to the notification systems, is that the time required to get the aide to the area is longer than the time the abductor needs to escape, or to hide the child. This is especially true since most, if not all, of the dog handlers will need to obtain a piece of clothing or other article with the child's scent.

One or more police-operated drone airplane(s) with a small camera and GPS device can increase the probability of finding the child by a rate proportional to its speed, battery life, and quality of camera. The drone airplanes are much less expensive than a helicopter, and can get lower in order to obtain more detailed pictures. The device can include a 3G network connection, such as the ones used by *smartphones* to feed back the images to a central location for analysis. The roads leading away from the school are its primary focus. It could follow vehicles to photograph the tags, and potentially the driver and passengers. These devices could also be enhanced with the same technology that is used in infrared sighting systems "which allows users to identify the heat signatures of individuals or objects day or night and in rain, fog and smoke" (City of Durham, n.d.).

Choice of Input Models

Assume there is only one kidnapper committing the abduction. The entity type representing the abductor's vehicle is labeled Car and it is depicted by a Van. Since the complete image of the model is too large to legibly fit on one screen shot, it will be displayed in the following pages in four separate sections. Figure 9 shows the complete image of the Arena model.

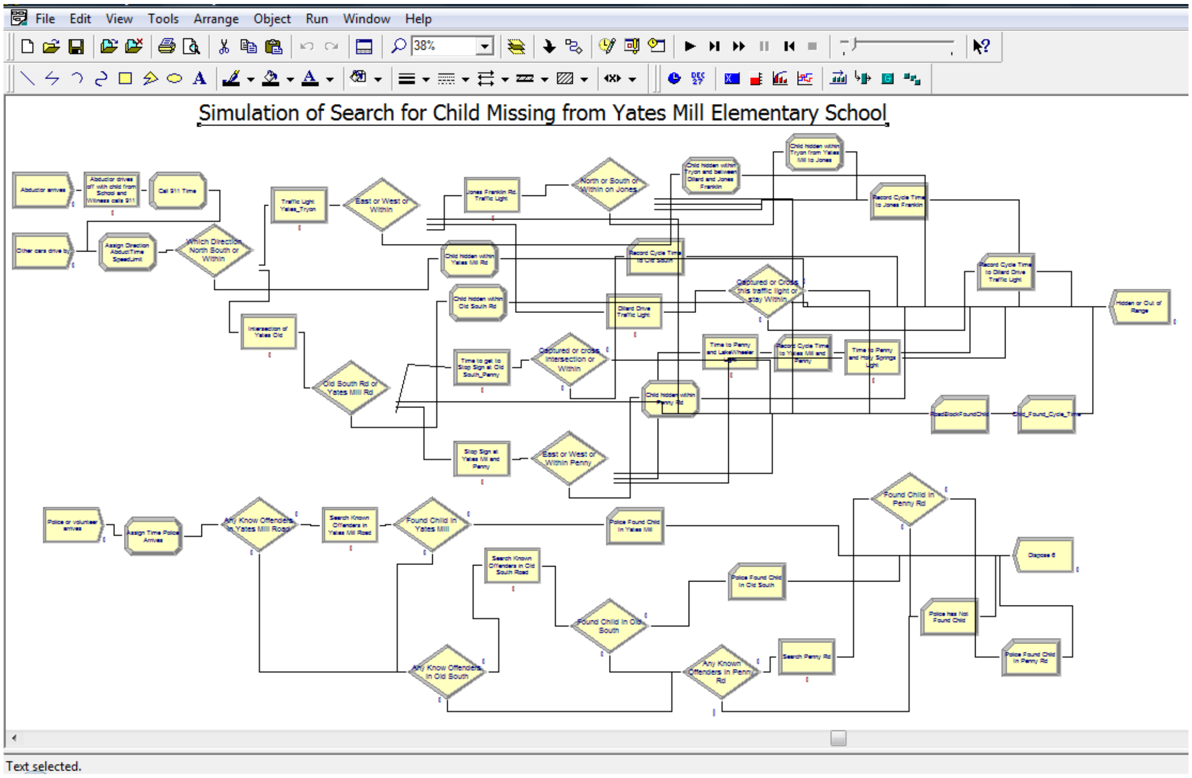


Figure 9. Complete Arena model of the Simulation of the Escape of the abductor and the Search for Child Missing from Yates Mill Elementary School.

Each section is enlarged for legibility and depicted again in the following images. In order to facilitate the understanding of the flow the rightmost blocks have been redisplayed in Figure 10.

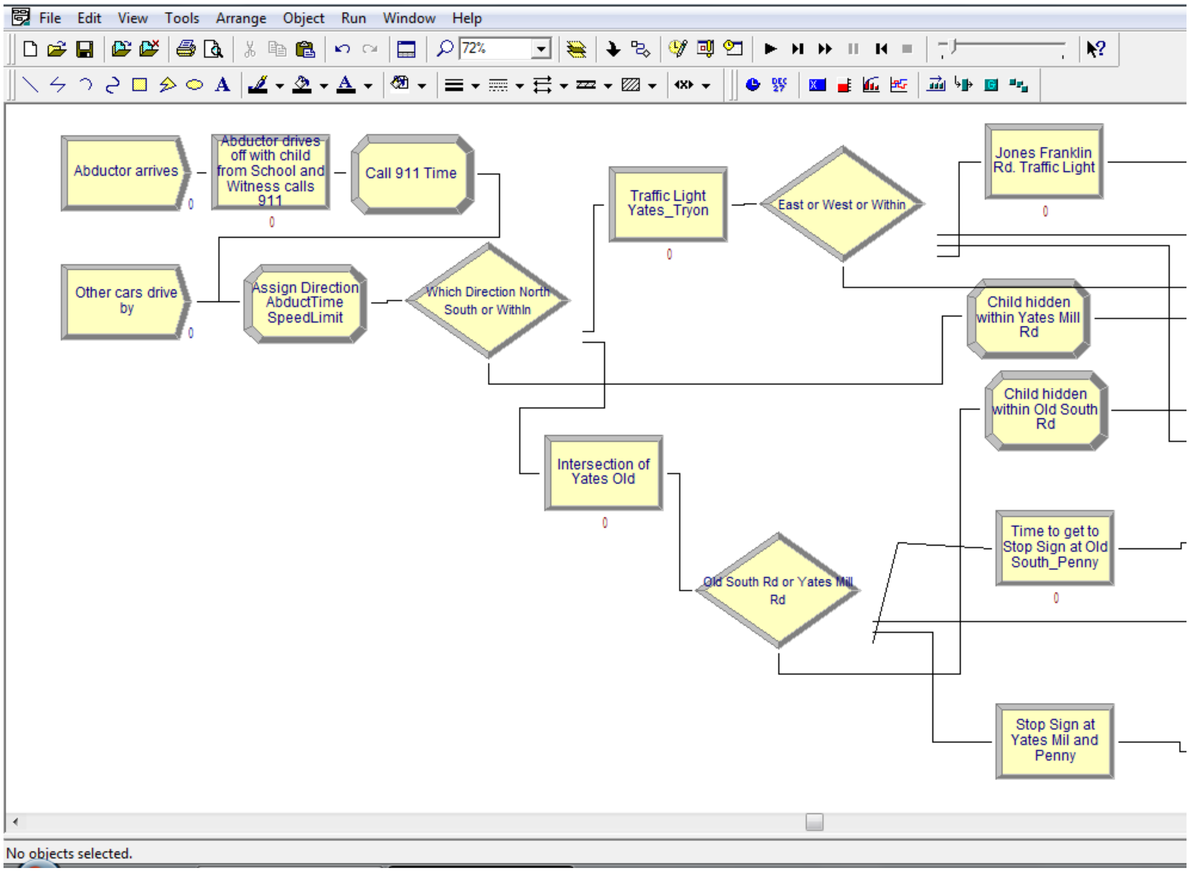


Figure 10. Arena model - top left section of the Simulation of the Escape of the abductor and the Search for Child Missing from Yates Mill Elementary School.

Figure 10 shows that the abductor drives off with the child from Yates Mill Elementary School and the witness calls 9-1-1. Other cars drive by on these same roads, but we will list the flow from the abductor's point of view:

I. Abductor decides which direction to go: north, south or stay within the closest intersections.

IA. Abductor reaches Yates_Tryon traffic light.

IA-1. Abductor decides which direction: east, west, or stay within the closest intersections.

IA-1.1 Abductor reaches Jones Franklin Rd. traffic light.

IB. Abductor reaches Yates - Old South intersection.

IB-1. Abductor decides which direction: Yates Mill or Old South Rd.

IB-1.1 Abductor reaches stop sign at Old South and Penny Rd.

IB-1.2 Abductor reaches stop sign at Yates Mill and Penny Rd.

Figure 11 projects the top right portion of the enlarged model of the escape.

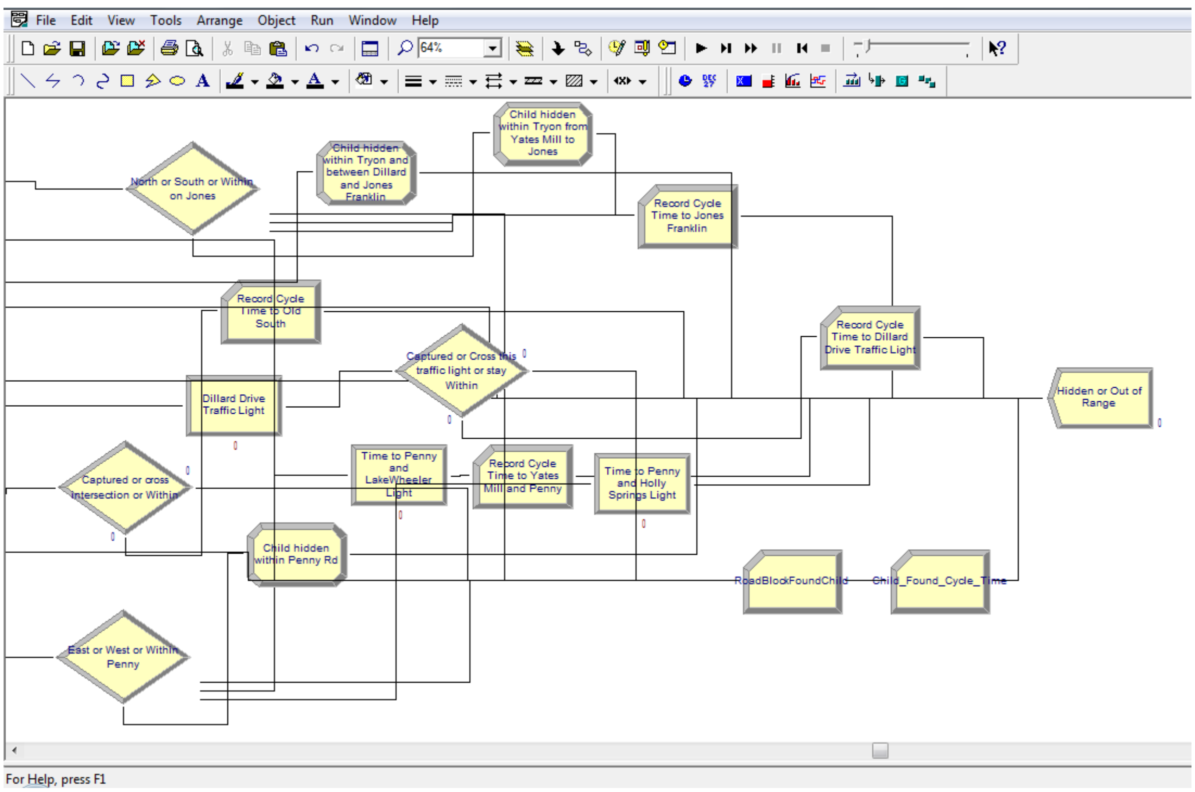


Figure 11. Arena model - top right section of the Simulation of the Escape of the abductor and the Search for Child Missing from Yates Mill Elementary School.

In Figure 11, the abductor continues to drive in the paths listed below:

IA-1.1 Abductor reaches Jones Franklin Rd. traffic light.

IA-1.1.1 Abductor decides which direction: north, south, or stay within Jones.

IA-1.2 Abductor reaches Dillard Dr. traffic light.

IB-1.1 Abductor reaches stop sign at Old South and Penny Rd.

IB-1.2 Abductor reaches stop sign at Yates Mill and Penny Rd.

IB-1.2.1 Abductor decides which direction: east, west, or stay within Penny Rd.

IB-1.2.1.1 Abductor heads towards Penny Rd. and Lake Wheeler Rd. traffic light.

IB-1.2.1.2 Abductor heads towards Penny Rd. and Holly Springs Rd. traffic light.

The last block of the flow on the model indicates the abductor and the child are hidden or are out of range. In the above subsections of the model, the abductor's potential paths are depicted.

Figure 12 is the bottom left section of the Simulation of the Escape of the Abductor and the Search for the Child Missing from Yates Mill Elementary School. This bottom section models the later arrival of the Police officer or volunteer. His decision path is modeled based on the knowledge of the location of the homes of past sex offenders.

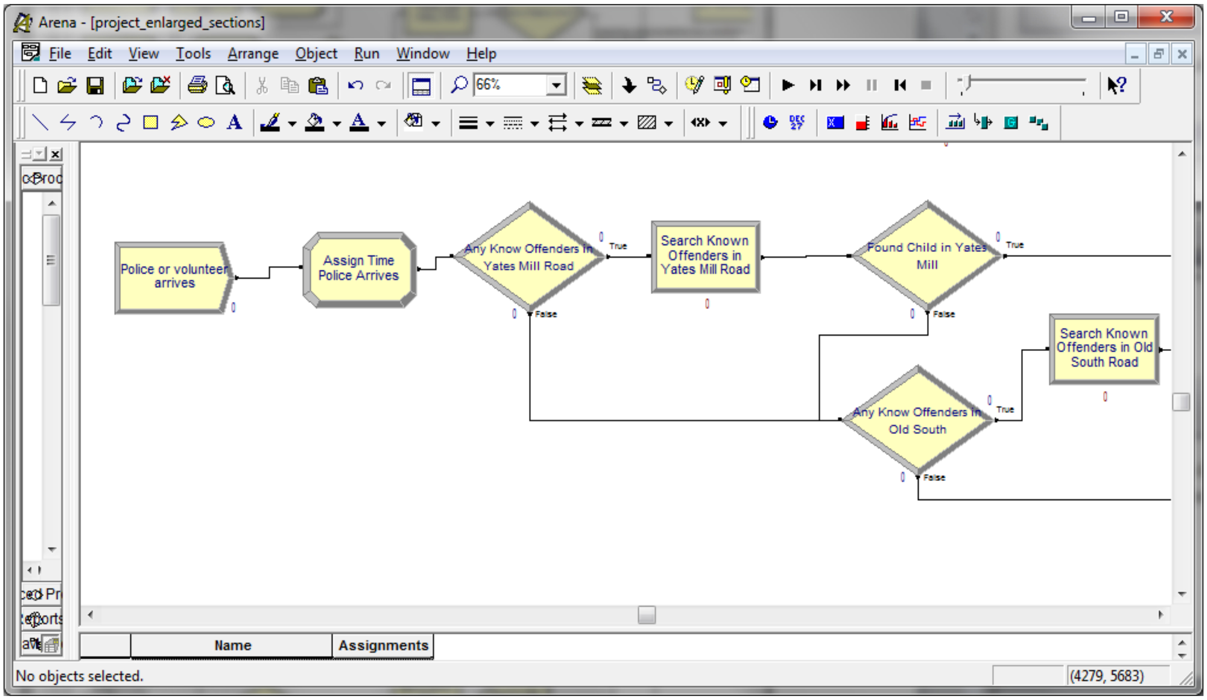


Figure 12. Arena model - bottom left section of the Simulation of the Escape of the Abductor and the Search for Child Missing from Yates Mill Elementary School.

In Figure 12, we can see the continued need of the human aides for a complete search. Even though it is impossible for officers to appear instantly at the scene of a crime, they are still essential given the small, but yet existing probability that the abductor could be in the neighborhood. The abductor could have hidden the child in his home already, and an officer can search the home without a warrant since a previous sentence as sex offender is already probable evidence. The officer's flow through the model is based on the knowledge of the location of the homes of past sex offenders.

I. Officer arrives and decides which direction to go based on the knowledge of the location of sex offenders on Yates Mill Road. If there are any sex offenders within Yates Mill Road, then he proceeds to the following search process before going to the next closest intersection.

IA. Officer searches known offenders on, or right off, Yates Mill Road.

IA-1. The next decision on behavior is based on whether or not the officer found the child. If he found the child then the model updates the statistics and the case in the model goes to the dispose block. Otherwise he goes to the next decision block.

IA-2 If there are any known sex offenders on Old South Rd., then he proceeds to search their homes as can be seen in the Figure 13:

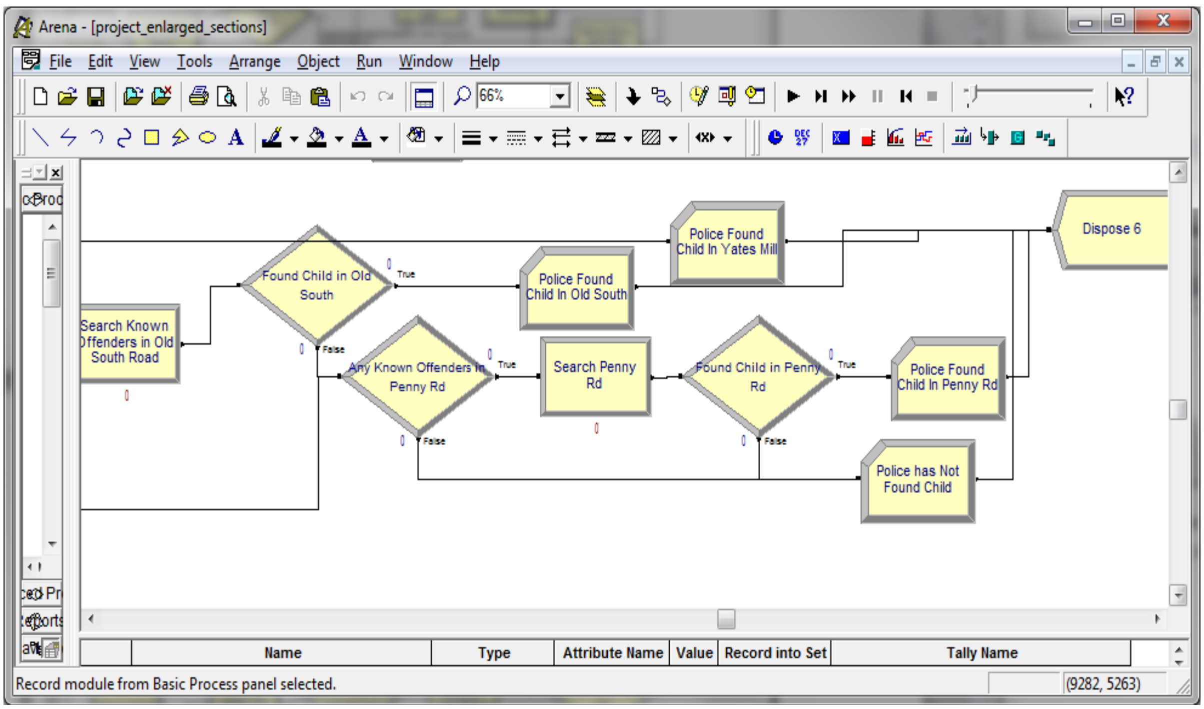


Figure 13. Arena model - bottom right section of the Simulation of the Escape of the abductor and the Search for Child Missing from Yates Mill Elementary School.

Figure 13 concludes the last part of the Arena simulation model. In this section the officer continues on these last steps if he went through the path of searching any known offenders on Old South Rd.:

I. If the Officer found the child while searching known offenders on Old South Rd., then the model updates the statistics and the case in the model goes to the dispose block. Otherwise the officer goes to the next decision block.

IA. If there are any sex offenders within Penny road, then the officer proceeds to the following search process.

IA-1. The Officer searches known offenders on, or adjunct to Penny Road.

IA-2. The next decision on behavior is based on whether or not the officer found the child. If he found the child then the model updates the statistics and the case in the model goes to the dispose block. Otherwise, the model updates the statistics to indicate that the officer has not found the child and the case in the model reaches its limit and goes to the dispose block.

Each of the processes listed in the descriptions of the above models involve a delay. The delays are influenced by the transfer times between each destination, which is proportional to the distance and the speed limit, and the time delayed by the traffic lights. An ideal system would be connected in real time, and it would receive the actual delays from the Department of Transportation. This is important since the scheduled time for each traffic light changes during rush hours.

The following section in distribution fitting will explain the detailed calculations used to approximate the distributions in the model.

Distribution Fitting

In this section, we incorporate knowledge of the area and the time of the event to approximate the distributions. The time of the event is defined to be the middle of the morning on a school day. Therefore, assuming it is the middle of the morning while one abductor arrives at the location of the school, other cars drive by with an exponential distribution of 0.9 minutes. This number would be higher earlier in the morning during car-pool time, and during job start times for individuals in the neighborhood. With the help of the Department of Transportation, a more accurate distribution could be built for every road in the city, and it could be specific to every half hour of the day. It would also vary on weekdays, and days when schools are closed.

The Search Known Offenders in Yates Mill Road process indicates an estimated minimum time to search the home of five minutes, an average time of 15, and a maximum time of 25 minutes. The “Delay Type” used in this case follows a Triangular distribution. The other search delays defined use the same distribution, except in cases where there is no offender living on that road.

The probability calculations on the flow are based on the information collected with the center point at the Yates Mill Elementary school. In the maps provided of the sex offender’s homes we can see that the count of the sex offender locations in the northern direction from the school is higher than the count in the southern direction. However, the close proximity of the offender to the school results in a higher likelihood of his being the kidnapper. Therefore, even though a first glance indicates that the offender is much more likely to travel north than he is to travel south, further calculations refine the probabilities closer to reality. That is because other areas of high probability, such as concealed areas, also affect the overall probability of the kidnapper traveling in that direction.

A. The first decision the abductor has to make is whether to go north to the next intersection on the road, or south to the next intersection on the road, or to stay within the two closest intersections. In the model “Direction_N_S” indicates a direction north or south directly from the school, and it follows a discrete distribution. The direction is given by a discrete distribution and it is selected like this:

1. The number of offenders within a one mile radius is two in the southern direction. One of these is within the two closest intersections. Therefore, since this is the closest location of high probability it has a higher weight than the others influencing the distribution. Its weight is 0.05 or five percent. This weight is higher than the ones assigned to the offenders who live outside the closest intersection, and those who live farther away.
2. The other offender within a one mile radius, but outside the first intersection, is located in the southern direction, and its weight is 0.04 or four percent. This weight is higher than the ones assigned to the offenders who live farther away, and slightly lower than the one assigned to the offender who lives within the first intersection. The percentage to add to the overall southern probability is four percent.
3. The number of offenders within a three mile radius and outside the one mile radius is ten in the northern direction and five in the southern direction. Both of these have a weight of 0.025 or 2.5%. It should be re-emphasized that the farther the offenders live, the lower their weight. The percentage to add to the overall northern probability is 10*2.5% = 25%. The percentage to add to the overall southern probability is 5*2.5% = 12.5%.
4. The number of offenders within a five mile radius is a total of 80 minus the 17 within

the three mile radius, which equal 63. These offenders are distributed as follows: 50 in the northern direction and 13 in the southern direction. These offenders live farther, and their weight is now 0.5%. The percentage to add to the overall northern probability is 50*0.5% = 25%. The percentage to add to the overall southern probability is 13*0.5% = 6.5%.

5. A high probability location is Yates Mill Pond Park within 3 miles. The percentage to add to the overall southern probability is 1*4% = 4%.
6. Another high probability location is Yates Mill Dump within 3 miles. The percentage to add to the overall southern probability is 1*8.5% = 8.5%.
7. Another high probability location is Lake Wheeler Park within 5 miles. This park has a much higher probability than the Yates Mill Pond Park because of its large concealed areas. The percentage to add to the overall southern probability is 1 * 9% = 9%. The overall totals sum approximately to 5% for the abductor to stay within the two closest intersections, 50% in the northern direction, and 45% in the southern direction. Therefore, the distribution of the direction is finally defined as a discrete distribution with these three probabilities.

B. The second decision the abductor has to make if he originally travels in the northern direction is whether to go east on Tryon Rd. to the next intersection, or west on Tryon Rd. to the next intersection, or to stay within the these two intersections. In the model Direction_E_W indicates a direction east or west from the traffic light at Yates Mill Rd. and Tryon Rd. The distribution of the direction is selected like this:

1. The number of offenders living east or west within a one mile radius is zero.

2. There is a farm within a one mile radius, and we assigned it a high probability of 9%.
3. A high probability location is Lake Johnson Park within three miles. This park has a high probability because of its large concealed areas. The percentage to add to the overall western probability is 1*10% = 10%.
4. The number of offenders within a three mile radius is four in the eastern direction and seven in the western direction. Both of these have a weight of 0.04. It should be re-emphasized that the farther the offenders live, the lower their weight. The percentage to add to the overall eastern probability is 3*4% = 12%. The percentage to add to the overall western probability is 7*4% = 28%.
5. The number of offenders within a five mile radius is 26 in the eastern direction and 15 in the western direction. These offenders live farther, and their weight is now one percent. The percentage to add to the overall eastern probability is 26*1% = 26%. The percentage to add to the overall western probability is 15*1% = 15%.

The overall totals sum approximately to nine percent for the abductor to stay within the closest intersections, 48% percent in the eastern direction, and 43% percent in the western direction. Therefore, the distribution of the direction is finally defined as a discrete distribution with the Arena function "DISC". The distance from Yates Mill Elementary to the Penny Rd. traffic light is 0.3 miles.

This section has explained the distribution fitting used in the first two intersections in the flow of the model. A few more intersections were added to the model and their distributions are deduced in the same form as the first two listed above. For the other calculations see Appendix A.

The following section will show the actual arena modules, and how they use the distribution fitting presented above.

Arena Modules

This section presents the modules used in the Arena simulation model. These modules use the distributions generated with the calculations described in the previous section.

Assume the Witness calls 9-1-1 within five minutes as indicated in the Arena Process dialog in Figure 14:

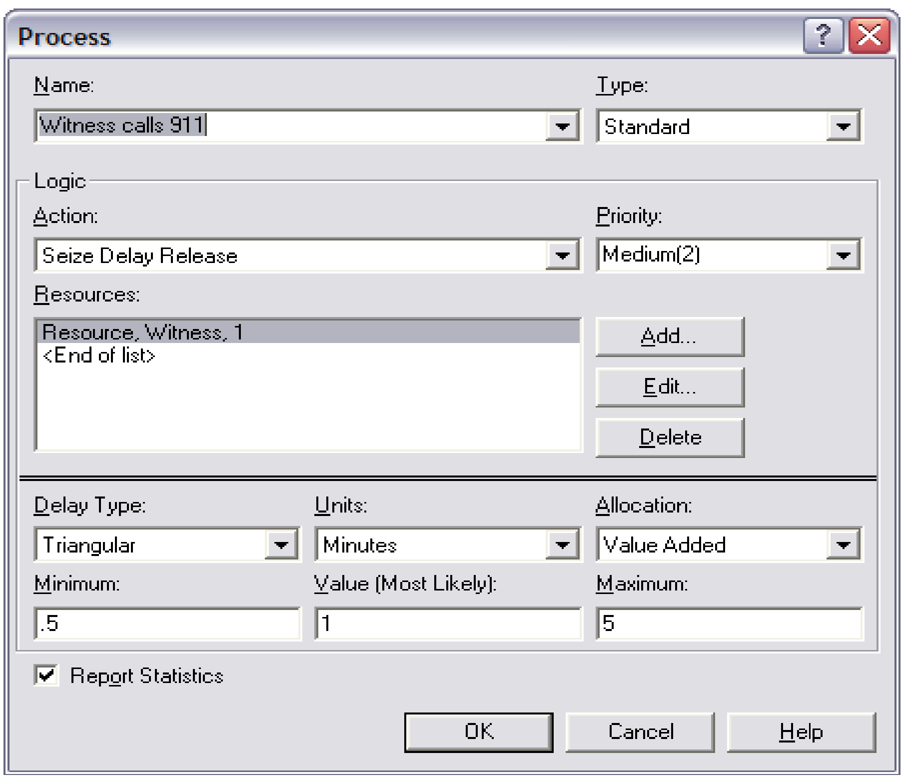


Figure 14. Arena - Process dialog: Witness call 9-1-1.

The delay type in the Process dialog is defined to be triangular with a minimum of 0.5

minutes, a maximum of five minutes, and a most likely value of one minute.

In the Decision block in Figure 15, the abductor decides which direction to go (North, South, or to stay within the current road.)

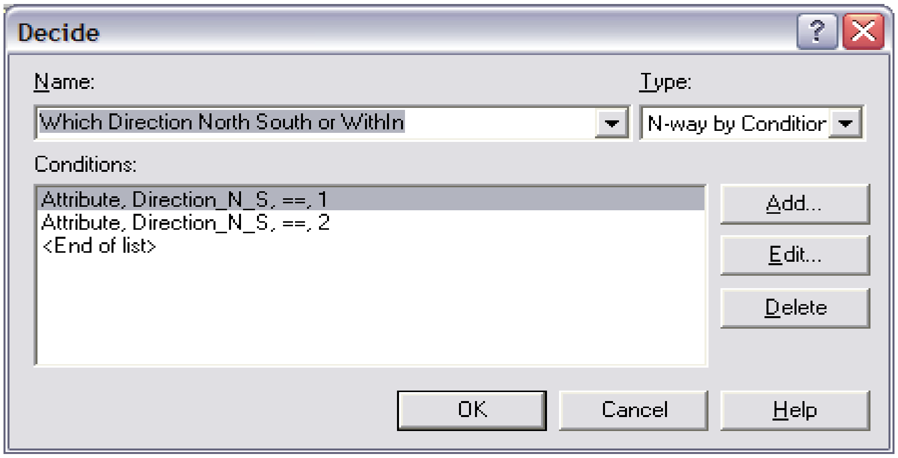


Figure 15. Arena - Decide dialog: North, South.

The “else” default of the decide block above defines that the child has been hidden within Yates Mill Road. The corresponding variable gets set to one.

When the abductor decides to go north to the next intersection on Yates Mill Pond Road, he reaches the traffic light at Yates Mill Pond Rd. and Tryon Rd. where he needs to decide whether to go east or west or to stay within the road. The real-life abductor would be unlikely to turn around. The small chance that he would do a complete u-turn would indicate that he has either heard the Amber Alert and that he is going to return the child, or that he is attempting to evade a chase in his current direction. In this last case, his state has changed to pursuit mode, and this state is outside the scope of this Arena simulation.

When the child abductor decides to go north to the next intersection on Yates Mill Pond Road, he reaches the traffic light at Yates Mill Rd. and Tryon Rd and we can see this in Figure 16.

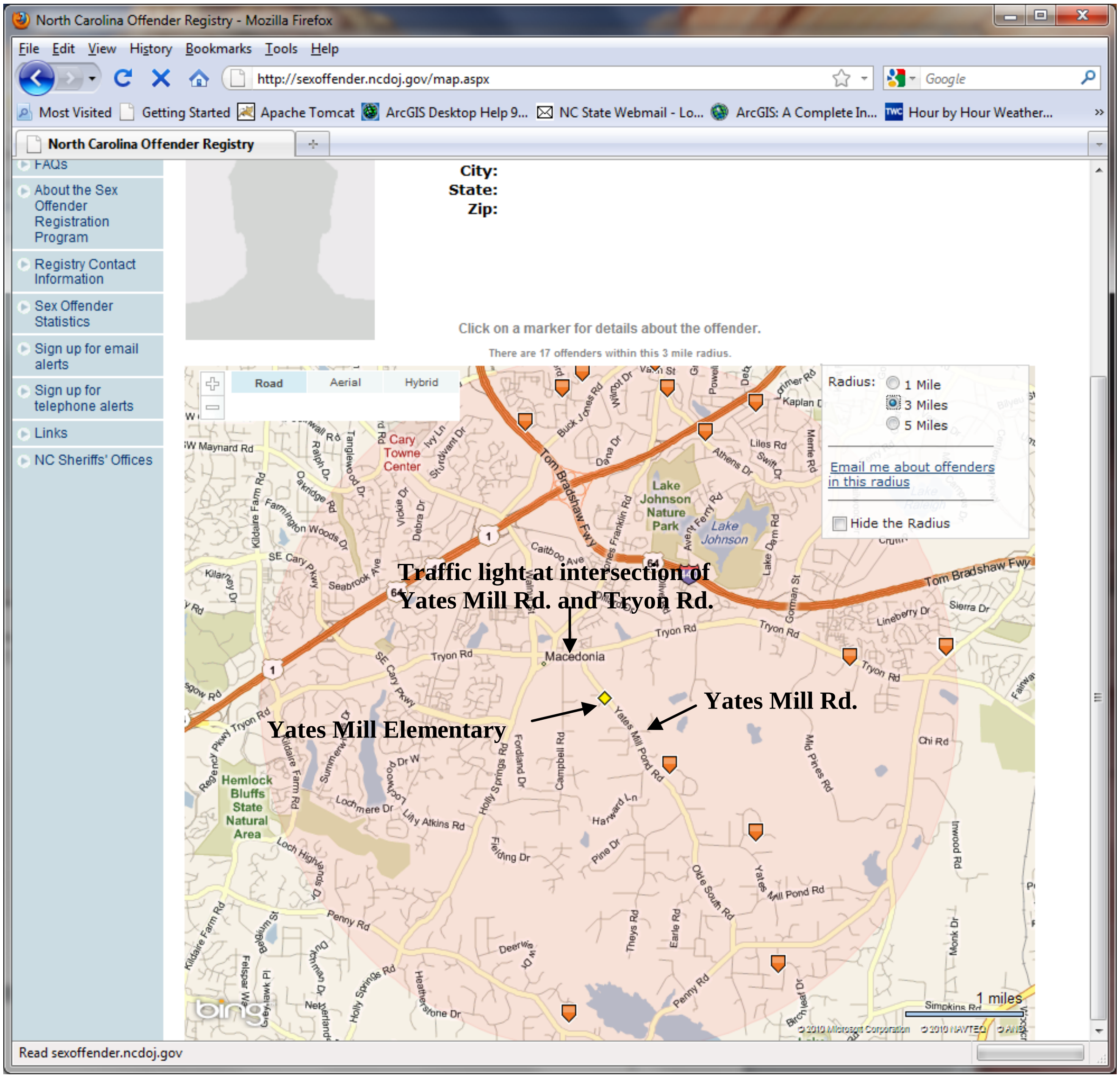


Figure 16. Intersection of Tryon Rd. and Yates Mill Rd. Traffic Light. This map uses the center point of the Yates Mill Elementary.

The location of the traffic light in the following paragraph is displayed above.

The Process block in Figure 17 represents the traffic light at the intersection of Yates Mill Pond Rd. and Tryon Rd. This process will be explained in detail due to its importance in the capture of the abductor. In addition to the traffic light delay, the process seizes a very important resource, which is the roadblock aide, and its name corresponds to its location: Road_Block_Aide_Yates_Tryon. When the roadblock aide represents a human searcher there is a car-search time added to the delay per vehicle. However, when this CAR_SEARCH_TIME has a value of zero and the quantity of the roadblock aide is one, it indicates that the presence of a camera at this location.

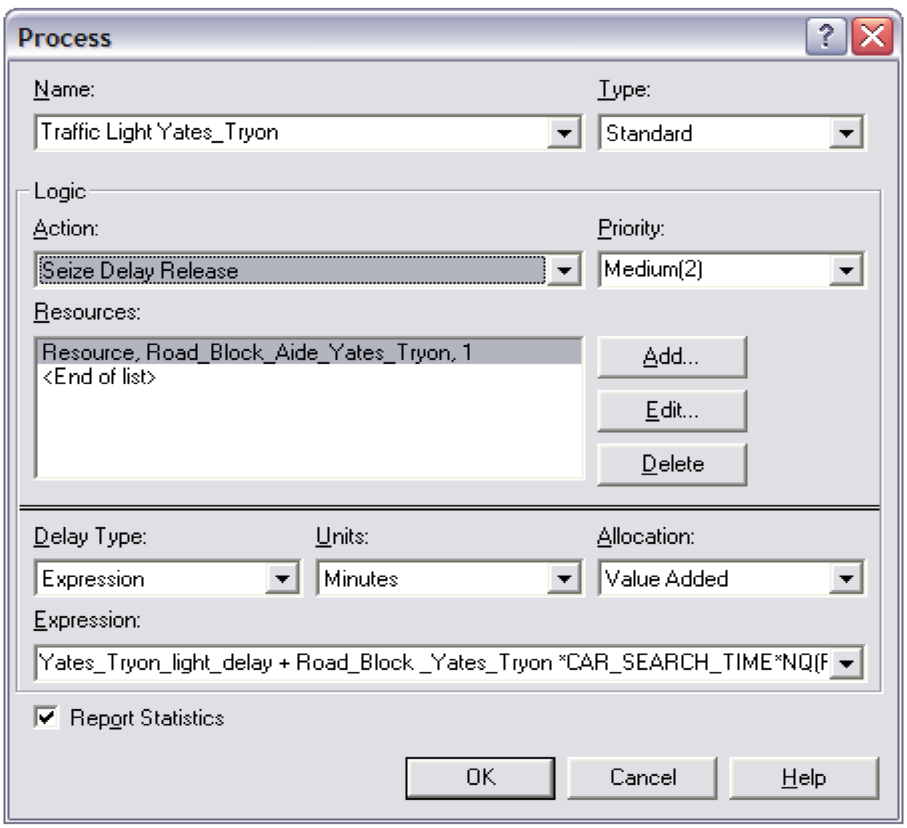


Figure 17. Arena - Process dialog: Yates Mill Rd., Tyron Rd. Traffic Light.

In the process block in Figure 17, the presence of a roadblock aide such as an officer or a camera will play an important part in the path decided in the following decision made.

In the Decision block in Figure 18, the abductor decides which direction to go (East, West, or to stay within the current road.) However, the most exciting part of the following decision block is that there is a potential for there to be a roadblock at this intersection, in which case if the entity type is abductor then he has been caught and the destination path is the RoadBlockFoundChild assignment block. This entry was not on the initial decision block above because it would have prevented the entire abduction in the first place, and it is unrealistic to have cameras everywhere where a child can be abducted. The abductor would be likely to avoid these initial cameras as well.

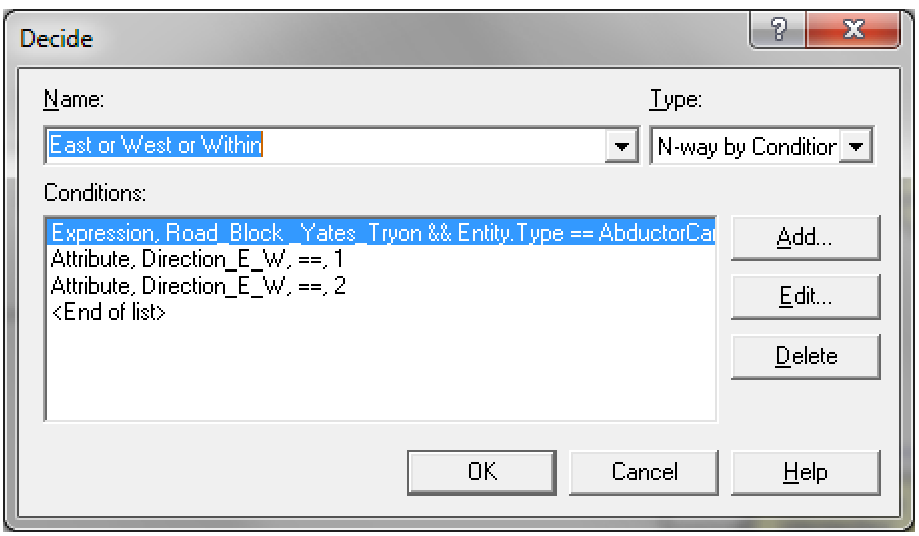


Figure 18.   Arena - Decide dialog: East, West.

The specific condition listed first is not entirely displayed in Figure 18, therefore, due to its great importance it will be redisplayed in Figure 19:

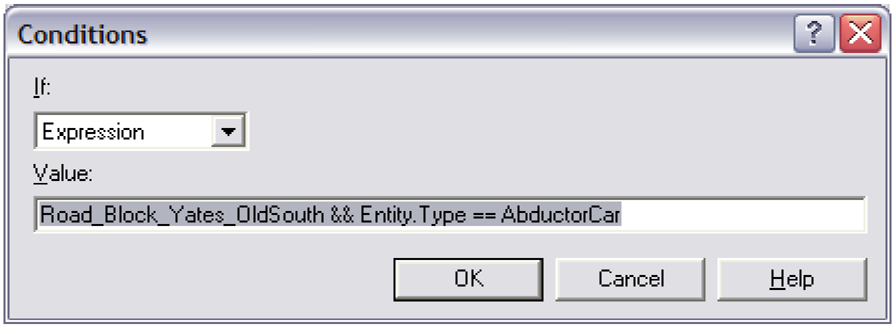


Figure 19. Arena - Conditions dialog.

Figure 19 is worth explaining in detail since it plays a crucial part in the capture of the abductor. It indicates the first path in the decision block and it is entered if there is a roadblock at this intersection. In this case if the entity type is abductor then he has been caught and the destination path to follow is the Road Block Found Child assignment block. It is hard to imagine a road block being available instantly at this intersection. However, a traffic camera present at the intersection that can capture the required detail would instantly direct police to follow the vehicle and if necessary to wait at his home or work place. In the cases where there is no previous knowledge of the tag or vehicle, the police can narrow their search to the vehicles that the traffic camera captured during the time of the event. All of them become instant primary suspects.

Decisions similar to the previous one follow the same explanation for the roadblock. The choice to go in the east direction would indicate the driver would next have to go through the traffic light at Jones Franklin Rd. and Tryon Rd.

When there is no roadblock, and when the 0.05% probability of the child being hidden within the current road is encountered, then the Arena model saves this information in a variable as shown in the Assign block in Figure 20.

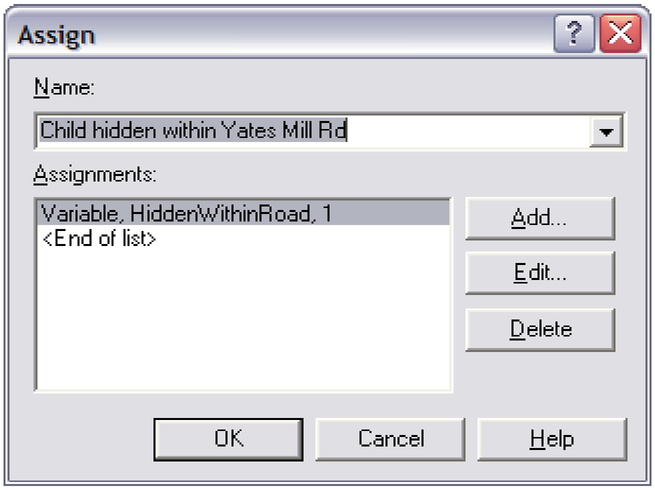


Figure 20. Arena - Assign dialog: Within Yates Mill Rd.

The assignment block is equivalent to the following formula:

HiddenWithinRoad = 1.

The number one in this assignment signifies that the child is hidden within Yates Mill Road. The other number possibilities are listed in the following list of the roads, and their equivalent images are similar:

1. Yates Mill Road. Child hidden within Yates Mill Road.
2. Tryon Road. Child hidden within Tryon Rd. and between Dillard Rd. and Jones Franklin Roads.
3. Old South Road. Child hidden within Old South Road.
4. Penny Road. Child hidden within Penny Road.

Finally, the Arena model requires a block named “Dispose” to indicate the entity has reached its final step within the model. This indicates that once the abductor has hidden within the specified road, or has reached one of the boundaries of the exercise where the continued search is outside the range of this simulation.

This dispose block concludes the explanation of the specific modules within the Arena model. These modules indicated the driving behavior and actions performed by the resources. Similar blocks had to be developed for every intersection added.

While the offender is escaping, the police officers may start to arrive and search the homes of sex offenders as shown on the bottom portion of the model. The bottom portion of the model has to be separated from the top since the officers do not need to stop at traffic lights. They are not subject to the same flow restrictions as the other cars.

If there are no known offenders on that road then the search time is set to zero as it is indicated on the "Search" module in Figure 21.

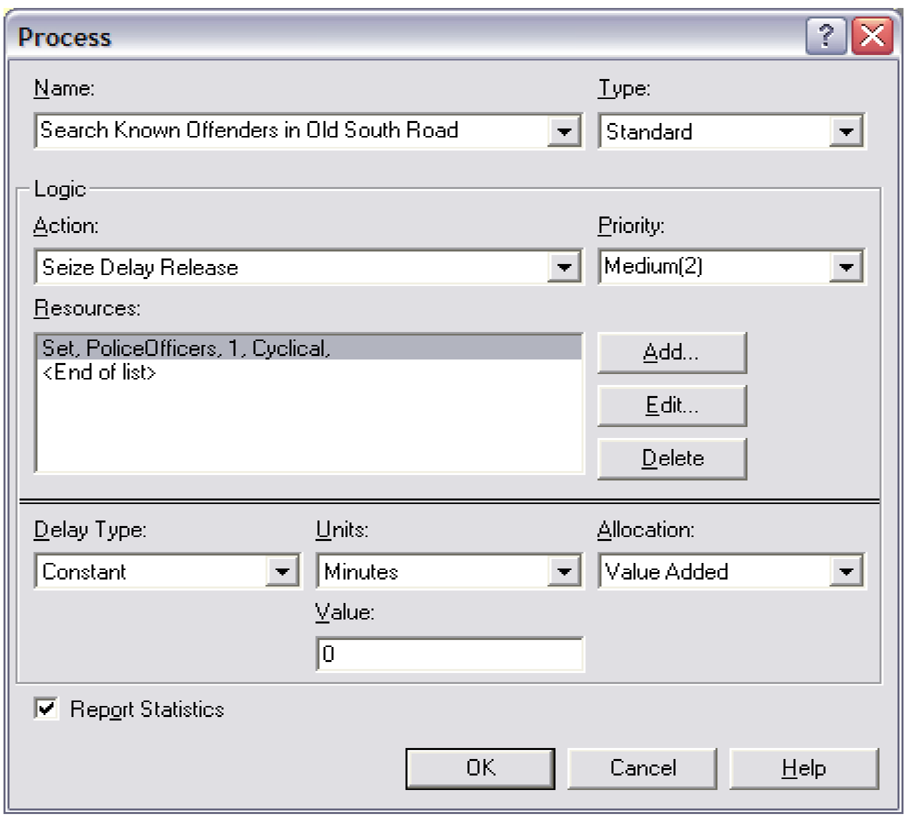


Figure 21. Arena Process Search Known Offenders in Old South Road.

In this module, we can see that the time for any of the officers to spend on Old South Rd. is zero since there are no known offenders in this section of that road. We still leave the module available in case in the future a known offender moves into the road.

On the contrary, on Yates Mill Rd. there is a known sex offender, and the process indicates an estimated minimum time to search the home of five minutes, an average time of 15, and a maximum time of 25 minutes. Figure shows the Process for this search:

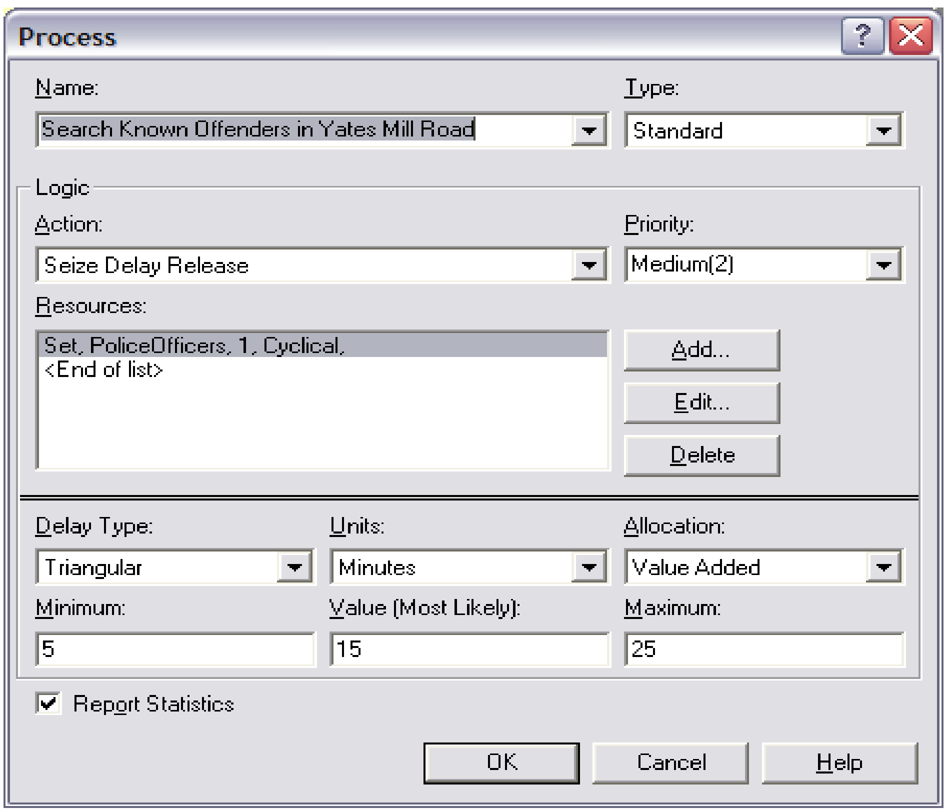


Figure 22. Arena Process Search Known Offenders in Yates Mill Road prior to Old South Intersection.

In this module we can see that the time for any of the officers to spend on Yates Mil Rd. is definitely more than on Old South Rd. since there is one offender on this road.

As we have seen, the number of Arena modules grows quickly as the boundaries expand. The modules are, however, similar in content. These just vary depending on the characteristics of the specific road.

Animation

Arena models can be built with images that represent the flow of the model. This is a visual aid that helps the user see their entities during the execution of the program. The Simulation Animation contains:

- Some Global pictures, including a clock (since time is critical), the school, a house.
- The entities, which are the van that contains the child and the abductor, and the police car.
- The resources, which are the police officers or volunteers, and the witnesses.
- The queues to search known offenders on each road. This delay varies depending on the time to gain entrance to the house.

Figure 23 contains the images used during the animation.

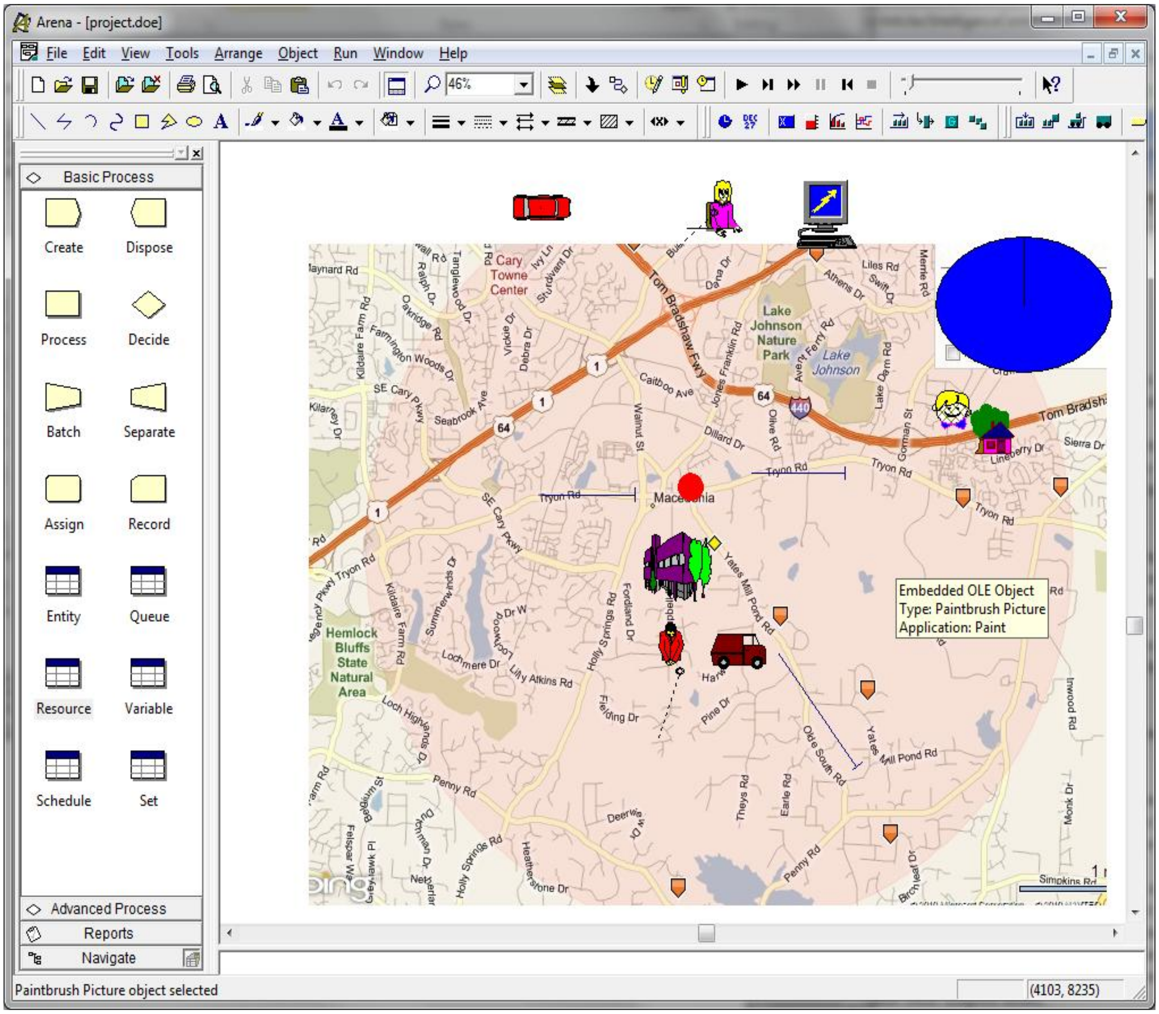


Figure 23. Arena - Simulation animation.

In this section, we can see the Arena animation is pleasing to the viewer, but it is better suited for much smaller systems. This system is large, it encompasses a large geographical area, and the vehicles end up the size of a whole block. The animation is however part of the enjoyment of developing a model.

In the analysis section, we will provide the statistical output generated by Arena and consider the validation to the model.

ANALYSIS

In the following sections, we will first provide the derivation of the number of replications needed for the desired precision. We then proceed to confirm that all paths can be traveled even when they have a very low probability. Finally, we display the Arena statistical output tables, and results.

Replications

This simulation models a terminating system and the analysis below corresponds to this specific type of terminating simulation. We used multiple simulation runs in order to obtain values that are statistically independent and identically distributed. These runs in Arena are programmed with a "Number of Replications" parameter. To calculate how many replications are needed for the 95% confidence interval of the RoadBlockFoundChild to be within ± 10% of its mean:

Let n be the number of replications needed to achieve the desired 95% CI width.

Let new_h be the desired half width of the 95% confidence interval.

Let old_h be the half width of the 95% confidence interval obtained with a preliminary run of Arena.

Let Avg be the mean of the RoadBlockFoundChild statistic obtained during a preliminary run of Arena, which is 0.8. This number was obtained with a run of Arena that used traffic-light cameras at every intersection.

Let n_old be the number of replications used during a preliminary run of Arena, which was ten.

Let PercentDesired be 0.1 since we want the 95% CI to be within ±10% of the mean.

First calculate the new half width to use in the formula that follows:

new_h = PercentDesired*Avg = 0.1*0.8= 0.08

Then, calculate the new number of replications needed to achieve the desired 95% confidence interval width, and round up the result

n = n_old * (old_h/new_h)^2 = 10 *(0.3/0.08)^2 = 10 * 14.0625 = 140.625

Table 4 contains the statistical results of runs of Arena with the use of traffic-light cameras at every intersection selected, and 141 Replications. Table 4 shows that the Average of the RoadBlockFound child statistic is now 0.9344, and its half width is now 0.04.

Therefore, we need 141 replications. We will refer to this number of replications in the following sections.

Verification

The Model was tested to ensure the entities follow the different potential paths. Even though some of the choices in the decision modules have lower probability, these are still eventually encountered. We will see on the tables in the Statistical Output Analysis section, and on the Sensitivity Analysis section that the results are consistent with the input.

Statistical Output Analysis

Table 1 lists the Entity Statistics generated by the run of the Arena model using 141 replications.

Table 1

Arena - Entity Statistics – Including Time Waiting in Queues and Travel Time

Entity

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AbductorCar	5.0507	< 0.29	0.9232	9.2994	0.9232	9.2994
OtherCar	3.7867	< 0.05	3.0450	4.5128	0.00	5.4464
PoliceCar	2.7816	< 0.36	0.00	9.4164	0.00	14.3976

NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AbductorCar	0.00	< 0.00	0.00	0.00	0.00	0.00
OtherCar	0.00	< 0.00	0.00	0.00	0.00	0.00
PoliceCar	0.00	< 0.00	0.00	0.00	0.00	0.00

Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AbductorCar	2.0514	< 0.40	0.00	12.4814	0.00	12.4814
OtherCar	2.2767	< 0.17	0.3849	5.1497	0.00	12.0443
PoliceCar	0.00	< 0.00	0.00	0.00	0.00	0.00

Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AbductorCar	0.00	< 0.00	0.00	0.00	0.00	0.00
OtherCar	0.00	< 0.00	0.00	0.00	0.00	0.00
PoliceCar	0.00	< 0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AbductorCar	0.00	< 0.00	0.00	0.00	0.00	0.00
OtherCar	0.00	< 0.00	0.00	0.00	0.00	0.00
PoliceCar	0.00	< 0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AbductorCar	7.1021	< 0.59	0.9232	19.5000	0.9232	19.5000
OtherCar	6.0634	< 0.19	3.5063	9.5683	0.00	16.5443
PoliceCar	2.7816	< 0.36	0.00	9.4164	0.00	14.3976

In this Arena table on Entity statistics, we can see that the Total Time spent on the system by the Abductor car was 7.1 minutes on average. The other vehicles had a similar expected value. Both the Abductor and the other vehicles spent about 2 minutes waiting at traffic lights.

Table 2 lists the times the entities spent in the various queues:

Table 2

Arena - Queue Times Accumulated for All Entities and Number Waiting in the Queues

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Abductor drives off with child from School and Witness calls 911.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Dillard Drive Traffic Light.Queue	0.00089487	< 0.00	0.00	0.03289785	0.00	0.1645
Jones Franklin Rd.Traffic Light.Queue	0.1754	< 0.04	0.00	1.4453	0.00	3.0686
Road Block at intersection Yates Old.Queue	2.6074	< 0.29	0.00	7.3808	0.00	13.1132
Time to get to Stop Sign at Old South_Penny.Queue	1.2072	< 0.10	0.00	1.7500	0.00	3.5000
Traffic Light Yates_Tryon.Queue	2.0389	< 0.24	0.08298904	6.1340	0.00	10.5387

Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Abductor drives off with child from School and Witness calls 911.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Dillard Drive Traffic Light.Queue	0.00021399	< 0.00	0.00	0.00822446	0.00	1.0000
Jones Franklin Rd.Traffic Light.Queue	0.04241166	< 0.01	0.00	0.5058	0.00	2.0000
Road Block at intersection Yates Old.Queue	1.7868	< 0.24	0.02505891	6.3274	0.00	10.0000
Search Known Offenders in Old South Road.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Search Known Offenders in Yates Mill Road.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Stop Sign at Yates Mil and Penny.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Time to get to Stop Sign at Old South_Penny.Queue	0.5272	< 0.05	0.00	0.8000	0.00	2.0000
Time to Penny and Holly Springs Light.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Time to Penny and LakeWheeler Light.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Traffic Light Yates_Tryon.Queue	1.3295	< 0.20	0.04190185	5.6737	0.00	11.0000

In this table of queue times, we can see the average time spent by the entities on the different traffic lights. We can see that the traffic lights are in use and cause delays. We can also see that the amount of traffic is not enough to generate a delay in the queue at the stop signs.

Table 3 lists the resource usage:

Table 3

Arena - Resource Usage – Includes Instantaneous Utilization and Number Busy

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Officer1	0.00	< 0.00	0.00	0.00	0.00	0.00
Officer2	0.00	< 0.00	0.00	0.00	0.00	0.00
Road_Block_Aide_Old_Penny	0.8130	< 0.02	0.2500	0.9000	0.00	1.0000
Road_Block_Aide_Penny_Holly	0.00	< 0.00	0.00	0.00	0.00	0.00
Road_Block_Aide_Penny_Lake	0.00	< 0.00	0.00	0.00	0.00	0.00
Road_Block_Aide_Tryon_Dillard	0.2334	< 0.02	0.00	0.4500	0.00	1.0000
Road_Block_Aide_Tryon_Jones	0.4090	< 0.03	0.00	0.8562	0.00	1.0000
Road_Block_Aide_Yates_Old	0.8651	< 0.03	0.2955	1.0000	0.00	1.0000
Road_Block_Aide_Yates_Penny	0.00	< 0.00	0.00	0.00	0.00	0.00
Road_Block_Aide_Yates_Tryon	0.8131	< 0.03	0.3154	1.0000	0.00	1.0000
Witness	0.1003	< 0.01	0.02741302	0.2400	0.00	1.0000

Number Busy	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Officer1	0.00	< 0.00	0.00	0.00	0.00	0.00
Officer2	0.00	< 0.00	0.00	0.00	0.00	0.00
Road_Block_Aide_Old_Penny	0.8130	< 0.02	0.2500	0.9000	0.00	1.0000
Road_Block_Aide_Penny_Holly	0.00	< 0.00	0.00	0.00	0.00	0.00
Road_Block_Aide_Penny_Lake	0.00	< 0.00	0.00	0.00	0.00	0.00
Road_Block_Aide_Tryon_Dillard	0.2334	< 0.02	0.00	0.4500	0.00	1.0000
Road_Block_Aide_Tryon_Jones	0.4090	< 0.03	0.00	0.8562	0.00	1.0000
Road_Block_Aide_Yates_Old	0.8651	< 0.03	0.2955	1.0000	0.00	1.0000
Road_Block_Aide_Yates_Penny	0.00	< 0.00	0.00	0.00	0.00	0.00
Road_Block_Aide_Yates_Tryon	0.8131	< 0.03	0.3154	1.0000	0.00	1.0000

In this table, we can see the usage of the roadblock aides when used at the intersections of Yates Mill Rd. and Tryon Rd., Tryon Rd. and Dillard Rd., Jones Franklin Rd. and Tryon Rd., and Old South Rd. and Yates Mill Rd.

In this section, we can see that the model is doing what it is called to do. We verified that there were other vehicles traveling the road, as expected. We also saw that the traffic lights caused delays, again as expected. And most important of all we saw roadblock aides activated.

In the next section we will see a validation of the model.

Validation

The distributions to fit the model and the parameters of each of the specific delay blocks need to comply with reality. The speed limits factor into the delay equations. The time it would take an officer to arrive is entered into the equation. This is important since there is a low probability that a police officer would be found close enough to help. The photo camera recording does not necessarily find the child, but it significantly increases the chances of finding the abductor. The model accounts for existing facts about the area, such as geographic information on concealed areas, which is important for an accurate list of probabilities assigned to the flow. A detailed geographical model is critical to simulate the decisions an abductor would make at every intersection of the roads.

In the tables we see that the results are reasonable for the missing child problem we are embarked to solve. The Distribution Fitting section shows the parameters that were fit to generate the execution times. The multiple challenges presented were listed in the Model Construction section. The results will be the listed in the following section.

In this section we have considered how the model accurately represents reality, and in the following section we will see the final results. The statistical results section and table below will continue to validate the model.

RESULTS

In this results section we can see a high potential for a traffic-camera at an intersection to successfully capture the image of the abductor's vehicle with the hidden child. The Tally statistical output generated by the Arena model is displayed since it contains the necessary information. The performance measure that is used to evaluate the efficacy of the different system configurations is the RoadBlockFoundChild Tally statistic, which we will see in the next table.

Table 4 shows the statistical results of runs of Arena with the use of traffic-light cameras at every intersection selected, and using 141 Replications:

Table 4

Arena - Statistical Results Including the Average of the Tally RoadBlockFoundChild Statistic

Tally

Expression	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
RoadBlockFoundChild	0.9433	< 0.04	0.00	1.0000	0.00	1.0000

Interval	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Child_Found_Cycle_Time	3.5078	< 0.33	0.00	11.4814	0.00	11.4814
Police has Not Found Child	2.7816	< 0.36	0.00	9.4164	0.00	14.3976
Record Cycle Time to Dillard Drive Traffic Light	5.2300	< 0.28	0.00	11.0016	0.00	12.4069
Record Cycle Time to Jones Franklin	6.2750	< 0.29	0.00	12.1069	0.00	14.9442
Record Cycle Time to Old South	7.1677	< 0.28	4.5000	10.9484	4.5000	16.5443

These statistics were generated when all the traffic-light cameras were used.

The results show that it is possible to capture the flow of an abductor with the child. We can see that there is a high potential for a roadblock at an intersection to successfully locate a child. As a reminder, this flag is set after crossing the intersection where there is a camera present. It is also only set if the entity type is abductor. In these cases, the abductor is caught and his destination path set the RoadBlockFoundChild variable to one. The 95% confidence interval listed in the table above is rewritten in the formula below

95% CI for Mean RoadBlockFoundChild = 0.9344 ±0.04

An average of 0.93 success rate is a good accomplishment for the usefulness of the roadblocks as seen above.

In conclusion, on Table 10 we see various 95% confidence intervals that show that on average the traffic-light camera at the Yates Mill Rd. and Tryon Rd. intersection, will capture the image of the abductor's vehicle 48.9% of the time, with a half-width of .08.

Sensitivity Analysis

In this section, we will see that while some parameters do not make a difference, others make a very visible difference. Some we modified within realistic limits, others we modified more to be able to see a difference. We modified distribution parameters and displayed the major differences. We also modified the number and location of the traffic-light cameras and displayed the contrast on a table.

The modification displayed in the following tables is based on a change of the distribution of the very first decision the abductor needs to make. Therefore, instead of using only five percent probability for the abductor to stay within the two closest intersections, we modified it to 35%. Instead of 50% probability of the abductor heading in the northern direction, we modified it to 30%. And, instead of a 45% probability of the abductor heading in the southern direction, we used 35%. Now his likelihood of heading south, or staying within the intersections, is slightly higher than heading north. Therefore, the average of the RoadBlockFoundChild statistic decreased to a 0.3121 as shown in figure 24.

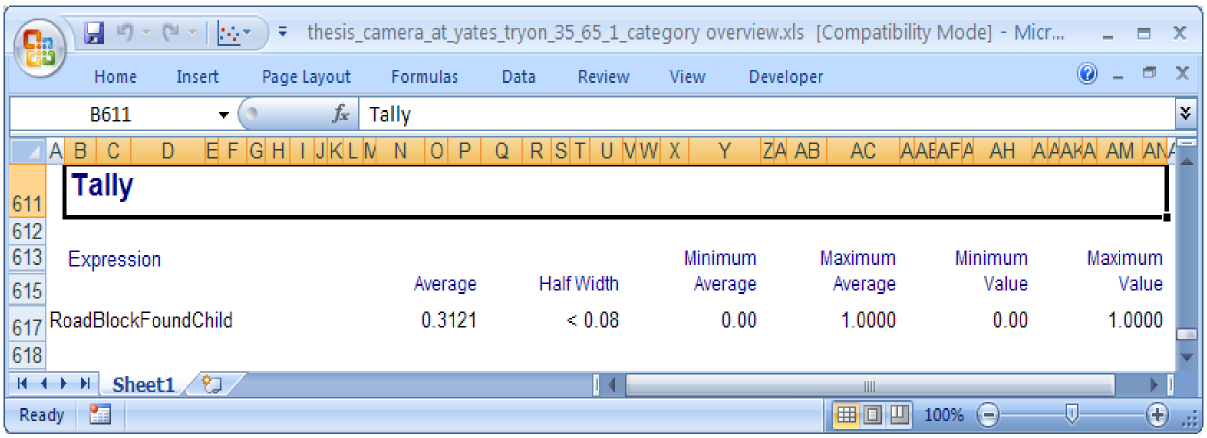


Figure 24. Arena result for RoadblockFoundChild statistic using distribution of directions as follows: north: 30%, south: 35%, and within: 0.35%.

This 0.3121 result is much lower than the 0.4894 result we obtained previously when the probability distribution for this decision was higher in the northern direction. Table 5 comparers these results.

Table 5

Comparison of Arena Results for RoadblockFoundChild Statistic Varying the Distribution of the Directions

Locations with Traffic-light Cameras	Number of near Locations with Camera	Average with Distributions within: 5%, north: 50%, south 45%	Average with Distributions within: 35%, north: 30%, south: 35%	Average with Distributions within: 5%, north: 30%, south: 65%
Yate Mill Rd. and Tryon Rd.	1	0.4894	0.3121	0.2978
Yate Mill Rd. and Old South Rd.	1	0.461	0.2978	0.6737

Table 5 shows how sensitive the model is to the change in the distributions assigned to the various directions that the abductor could take.

The values in Figure 25 are the most affected by a variation of distribution on the probabilities associated with the north and south directions. This is the first decision the abductor makes when he leaves the school. The change is noticeable when there is approximately an equal chance of heading north, south, or staying within the closest intersections.

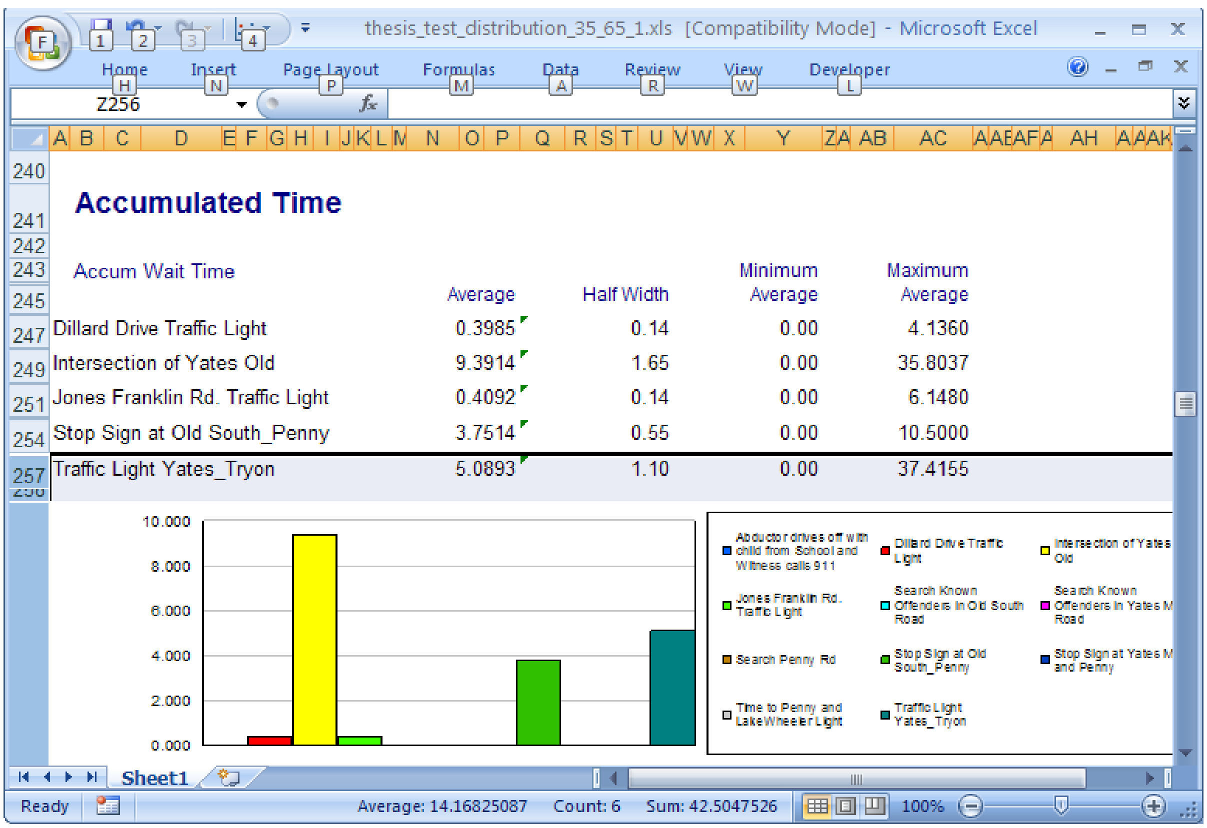


Figure 25. Arena – Accumulated Wait Time for approximately equal distributions.

Figure 26 shows values for the distribution used in the model. These distributions were calculated in the Distribution Fitting section of the document. The difference is most visible if we notice that on the chart the Time axis only goes up to 10 minutes, whereas in Figure 27, the Time axis goes up to 20 minutes.

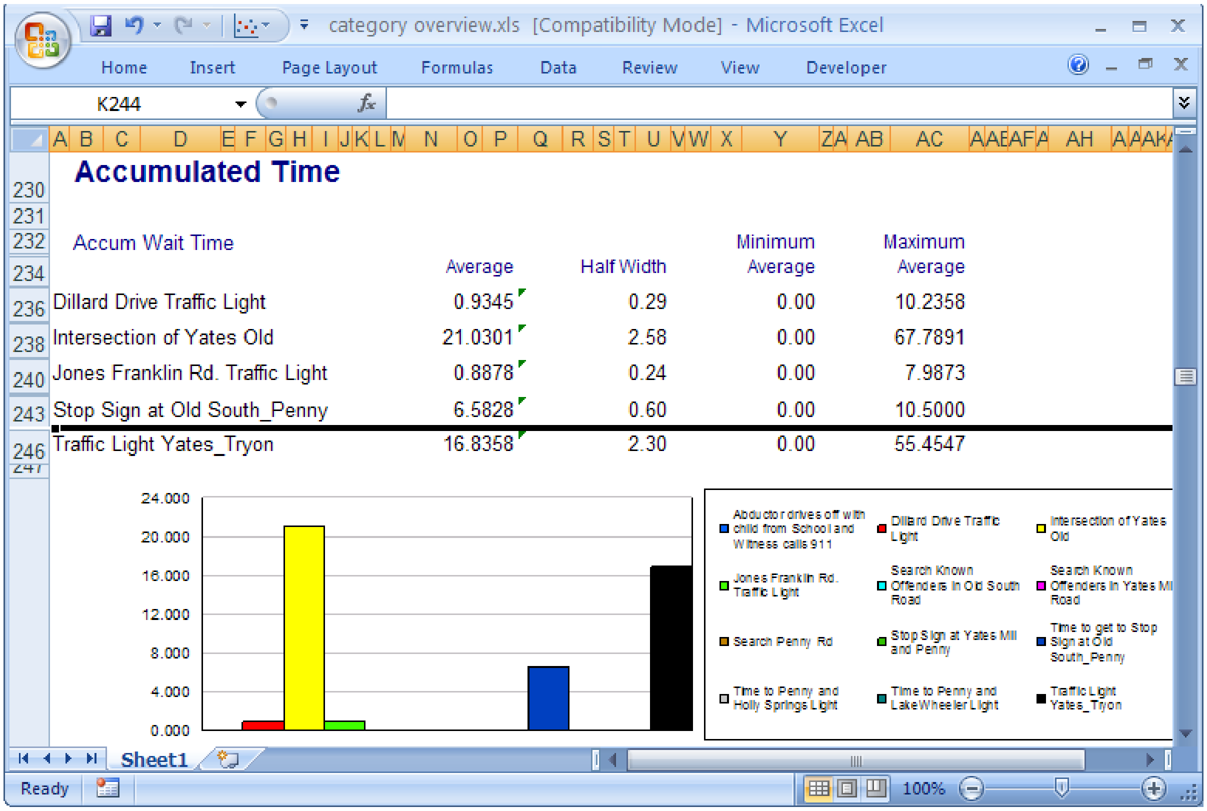
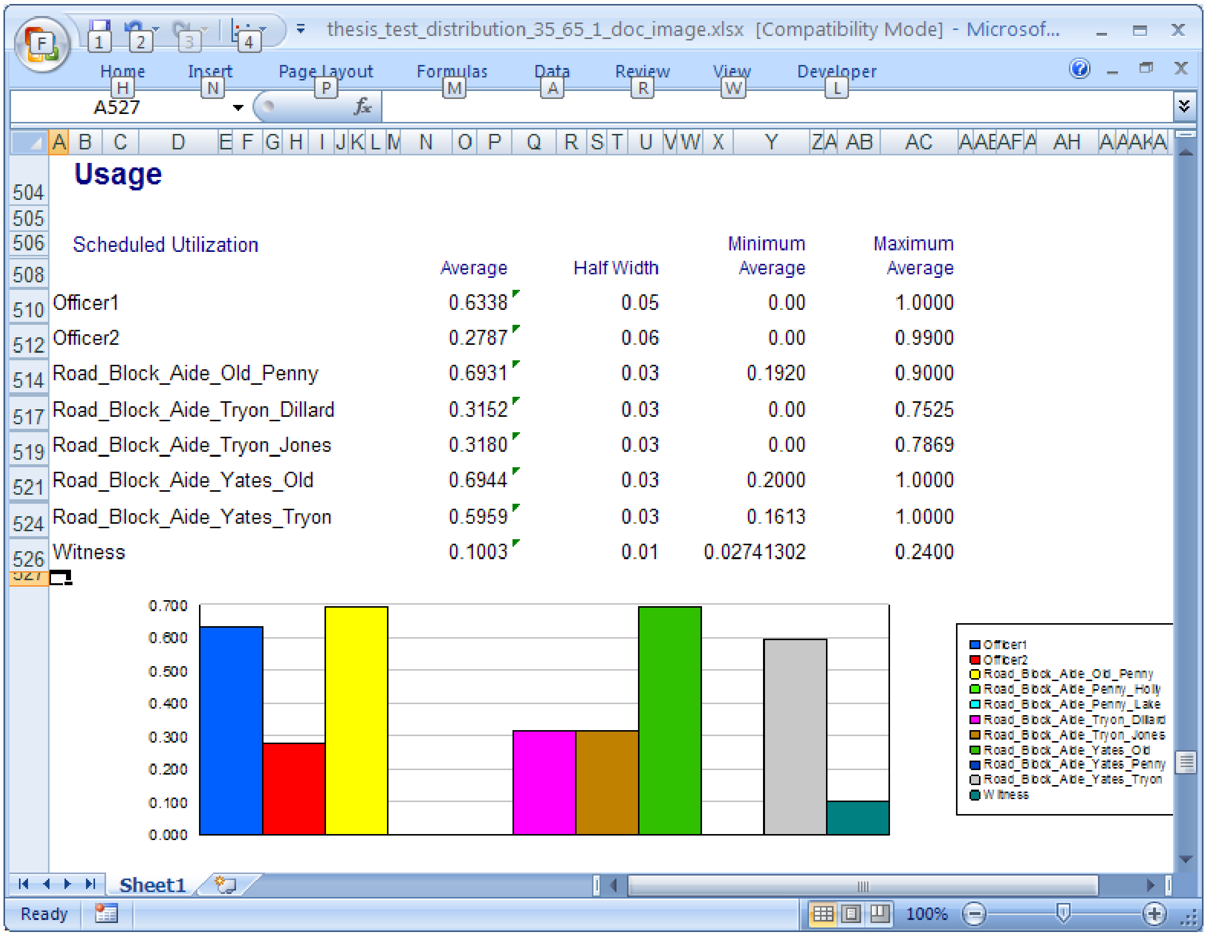


Figure 26. Arena – Accumulated Wait Time for the distributions used in the model.

In the above model, notice that the Accumulated Wait Time at the intersections above is no longer as evenly distributed as it was on the previous table. This is the result of the distributions following the probabilities calculated in the Distribution Fitting section of the document.

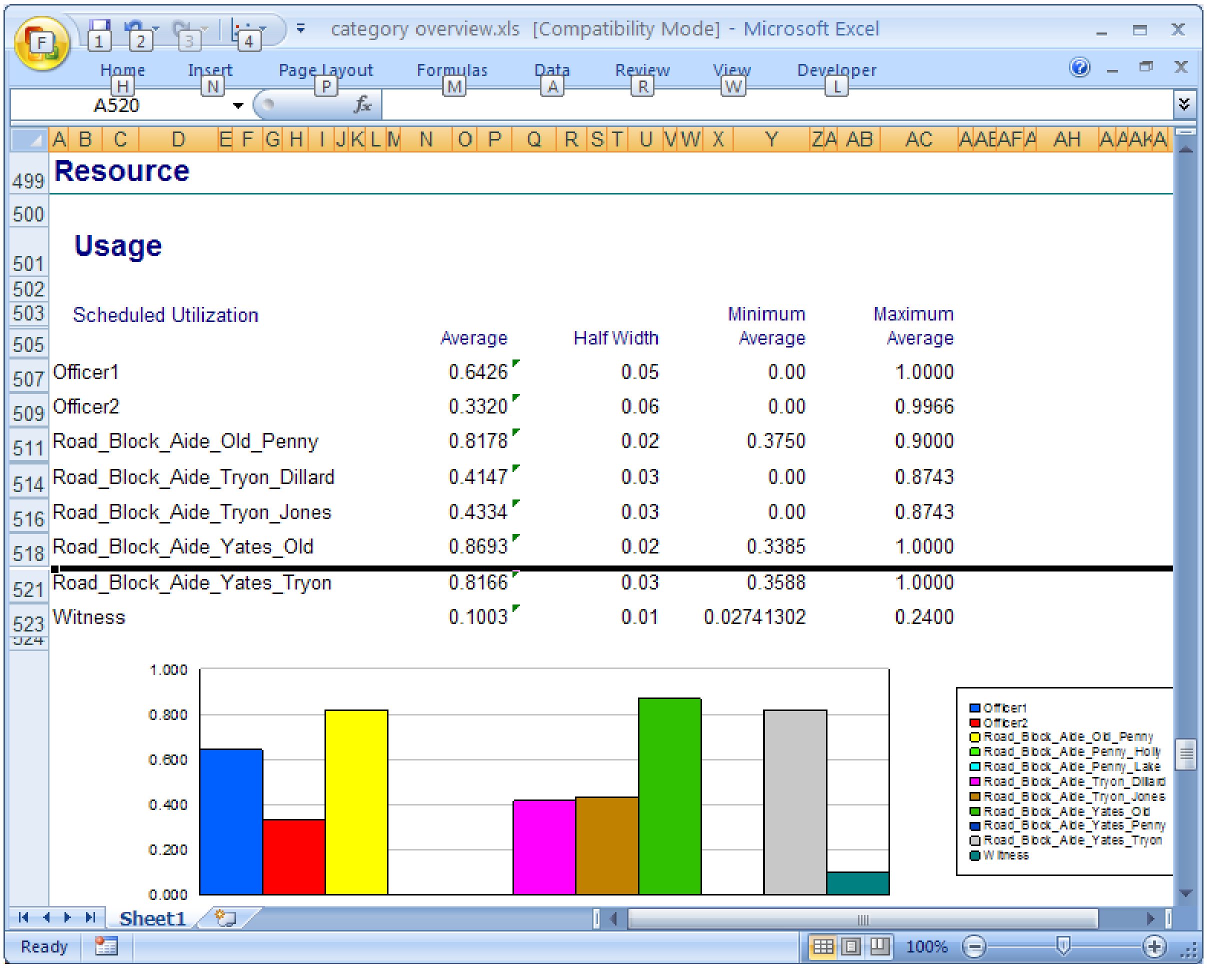
In figures 27 and 28, we can see another good comparison between the effects of varying the distribution. It is the scheduled utilization of the Arena "Resources." The first one is more evenly distributed. This occurs since the initial distribution to go north or south or stay within the road is approximately equally distributed:



	Average	Half Width	Minimum Average	Maximum Average
Officer1	0.6338	0.05	0.00	1.0000
Officer2	0.2787	0.06	0.00	0.9900
Road_Block_Aide_Old_Penny	0.6931	0.03	0.1920	0.9000
Road_Block_Aide_Tryon_Dillard	0.3152	0.03	0.00	0.7525
Road_Block_Aide_Tryon_Jones	0.3180	0.03	0.00	0.7869
Road_Block_Aide_Yates_Old	0.6944	0.03	0.2000	1.0000
Road_Block_Aide_Yates_Tryon	0.5959	0.03	0.1613	1.0000
Witness	0.1003	0.01	0.02741302	0.2400

Figure 27. Arena – Scheduled Utilization of the resources for approximately equal distributions.

We notice that in figure 27, the Schedule Utilization Axis goes up to 0.7, whereas the Scheduled Utilization Axis on the table in Figure 28 goes up to 1.0. The scheduled utilization on three of the intersections increases by about 20%.



Resource

Usage

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
Officer1	0.6426	0.05	0.00	1.0000
Officer2	0.3320	0.06	0.00	0.9966
Road_Block_Aide_Old_Penny	0.8178	0.02	0.3750	0.9000
Road_Block_Aide_Tryon_Dillard	0.4147	0.03	0.00	0.8743
Road_Block_Aide_Tryon_Jones	0.4334	0.03	0.00	0.8743
Road_Block_Aide_Yates_Old	0.8693	0.02	0.3385	1.0000
Road_Block_Aide_Yates_Tryon	0.8166	0.03	0.3588	1.0000
Witness	0.1003	0.01	0.02741302	0.2400

Figure 28. Arena – Scheduled Utilization of the resources for the distributions used in the model.

In Figure 28, we see major differences between the utilization at the various intersections. Some of the utilization is almost double that of the others. This is more realistic since it follows the distribution fitting calculated based on the higher number of known sex offenders living in some areas. Next, we use the Process Analyzer to do a lot of the work of modifying parameters for us.

We used the Process Analyzer (PAN) tool that comes with Arena to vary the different variables and see if the results improved. This is an excellent tool that prevents the need for several manual changes. The downside is that it does not generate all the statistical output associated with the manually inputting parameter changes to the various models. In order to use PAN, we had to uncheck all statistics in the “Dispose” blocks and in the “Project Parameters” and use “Batch Run”.

PAN allows us to enter the control variables, and in our case these are all of the following RoadBlock variables at the different intersections:

- Road_Block _Yates_Tryon, where Yates is short for Yates Mill Rd.
- Road_Block _Yates_Penny, where Yates is short for Yates Mill Rd.
- Road_Block_Tryon_Dillard, where Dillard is short for Dillard Rd.
- Road_Block_Yates_OldSouth, where Yates is short for Yates Mill Rd.
- Road_Block_Tryon_Jones, where Jones is short for Jones Franklin Rd.
- Road_Block_Penny_Holly, where Holly is short for Holly Springs Rd.
- Road_Block_Penny_Lake, where Lake is short for Lake Wheeler Rd.
- Road_Block _Penny_Old , where Old is short for Old South Rd.

This selection module is shown in Figure 29:

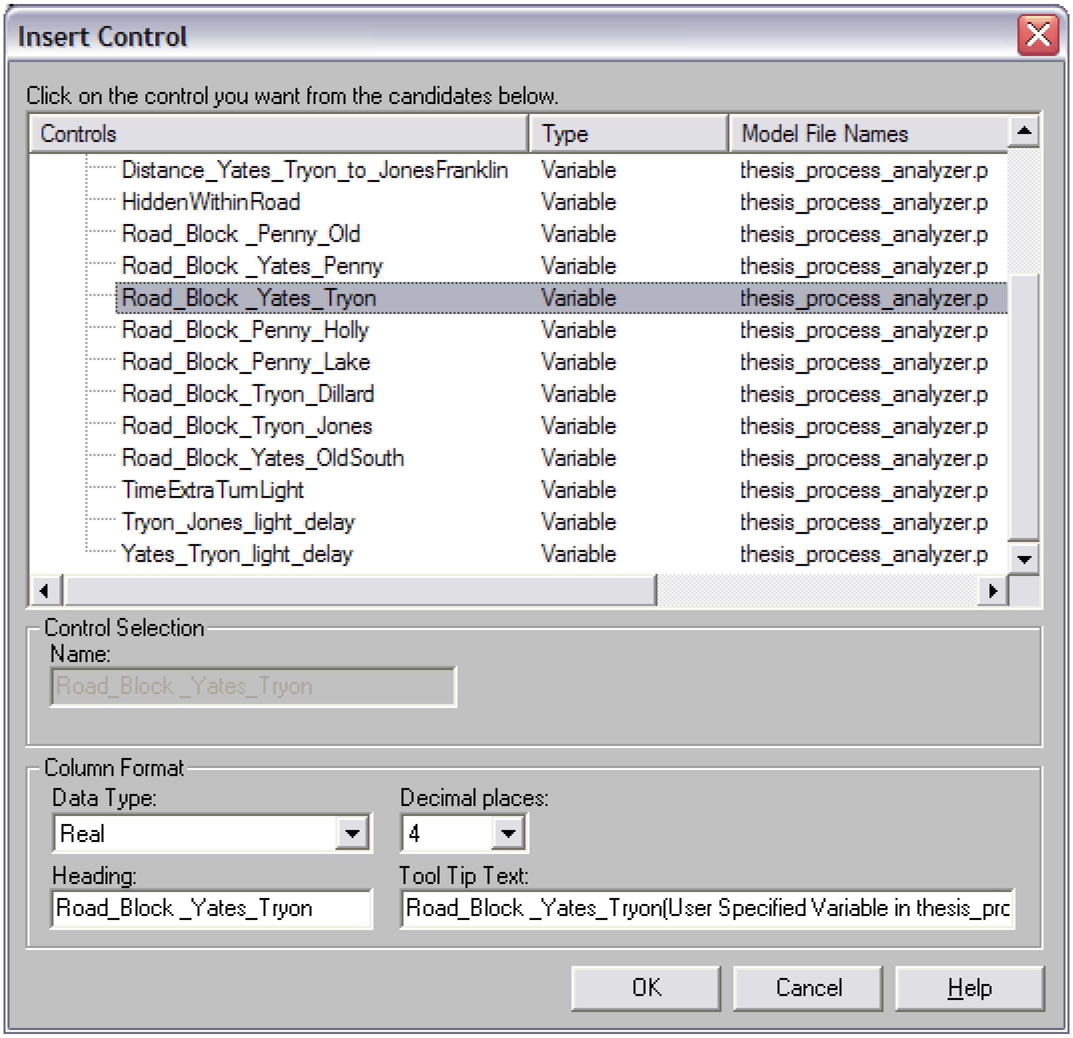


Figure 29. Insert Control in Process Analyzer.

This Insert Control in Figure 29 shows clearly the names of every input variable we would like to test.

Continuing the use of the Analyzer, we then select the scenarios to vary the number of roadblocks:

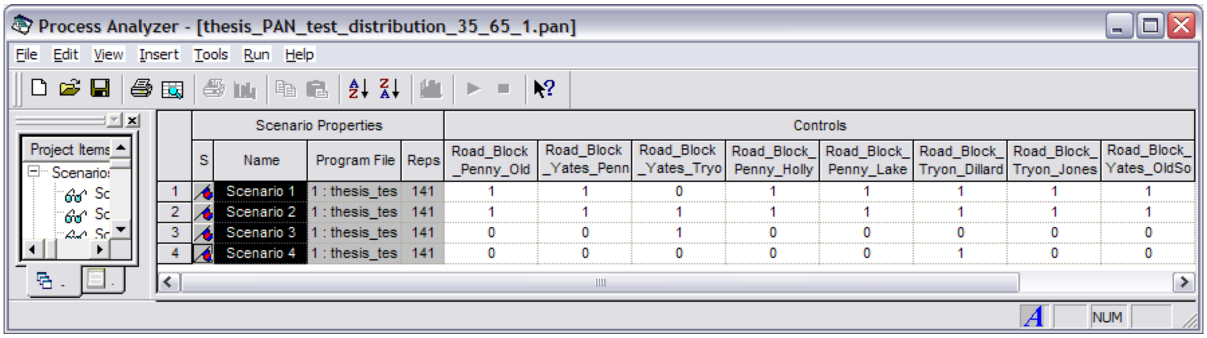


Figure 30. Scenarios in Process Analyzer with control variables.

In figure 30, we see different scenarios using the process analyzer. We vary the Roadblock at each intersection to compare the results of the response variable, which in our case is the RoadBlockFoundChild Tally statistic.

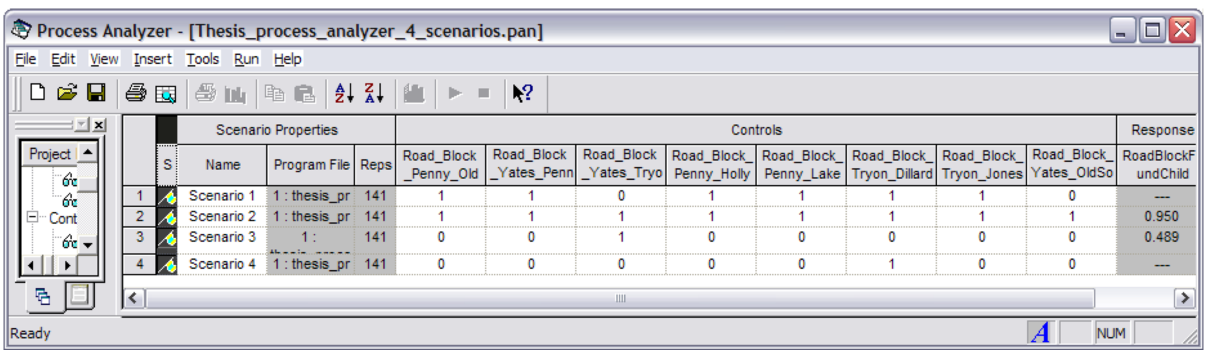


Figure 31. Response for various Scenarios in Process Analyzer.

In Figure 31, we see the response to different scenarios using the process analyzer. The best response is obviously to have a Roadblock at each intersection. It provides a 95% chance of capturing the abductor or his image, whether it's accomplished by a human roadblock, or by a still camera, or even by a video camera if available. Since it is unrealistic to be able to instantly afford roadblocks at every intersection, the next best response is to have a traffic-camera at the intersection of Yates Mill Rd. and Tryon Rd. This traffic-camera provides a 48.9% chance of capturing the abductor's image. This process analysis allows us to vary the input variables and compare the results of the response variable, which in our case is the RoadBlockFoundChild Tally statistic.

In Table 6, we can see the sensitivity associated with the location of the various cameras on the field. The average RoadBlockFoundChild Tally statistic is compared varying the locations and the total number of the cameras used. Table 6 also shows that as the number of traffic-light cameras increases, the probability of finding the child increases.

Table 6
Statistical Summary and Comparison- Comparing RoadblockFoundChild Statistic Results of Runs of Arena Models with the Use of 141 Replications Varying the Intersections with Cameras

Locations with Traffic-light Cameras	Number of near Locations with Camera	Average	95% Half Width
No_cameras	0	0	0
Yates Mill Rd. and Penny Rd.	1	0.2766	< 0.07
Yates Mill Rd. and Old_South Rd.	1	0.461	< 0.08
Tryon Rd. and Dillard Rd.	1	0.1844	<0.06
Tryon Rd. and Jones Franklin Rd.	1	0.227	<0.07
Yates Mill Rd. and Tryon Rd.	1	0.4894	<0.08
Two Intersections: 1) Yates Mill Rd. and Tryon Rd. 2) Yates Mill Rd. and Old_South Rd.	2	0.9504	<0.04

As we can see Table 6, using traffic-light cameras at the intersections directly north and directly south of the abduction increases the probability of finding the child to about 95%. The other five percent corresponds to the possibility of the abductor living within the two intersections. The police officers' work in the model is not as part of a roadblock, but as part of a search. Within the boundaries of the model, the officers search only the few homes of offenders on the immediate area. Even though the officers were searching selected homes of high probability offenders they were still searching without the feedback of the cameras. Therefore that feedback is definitely essential to utilize the police officers resource efficiently.

In this section, we can see sensitivity results associated with the location of the various cameras on the field. The next section is a discussion of the results.

DISCUSSION

Since it is unlikely for the human aides to be able to arrive at the nearest locations in time to set up roadblocks, the simulation includes the use of traffic-light cameras at the same intersections. The statistical analysis table above shows that as the number of traffic-light cameras increases, the probability of finding the child increases. However, having the traffic-light cameras strategically located at some of the intersections yields a higher benefit than at others. In this model, the traffic-light camera at the Yates Mill Rd. / Tryon Rd. intersection yields a slightly higher probability of finding the child than at any of the other intersections. Therefore, installing a traffic-light camera at the intersection of Yates Mill Rd. and Tryon Rd. is the most useful and cost effective action to take.

CONCLUSION AND RECOMMENDATIONS

The results mean that even though it is very difficult to find a missing child, some changes can make a significant difference for a higher percentage of children. The most important discovery associated with this thesis was the fact that instead of needing to worry about the *cost* of the suggested solution, we need to plan for the *profit* it generates. This is because the red-light cameras are free to the cities, and even generate profit. There are private companies that install and maintain them for free, and keep a percentage of the revenue from the tickets issued to those who run the red-light. In addition, the suggested solution may be profitable, and there are several winning parties. The town of Cary made a one year profit of $86,135 in 2008. This money went to the Wake County Public School System (Lamb, Cantrell, & Gardner, 2009). There is also another elementary school in one quadrant of the intersection of Yates Mill Rd. and Tryon Rd.

Therefore, our recommendation is to install a traffic-light camera at the intersection of Yates Mill Rd. and Tryon Rd., and start to consider the implementation of this same method at the rest of the high-probability traffic lights.

Existing Red Light Cameras

Red Light cameras are already beneficial to communities. Multiple studies have documented analysis of their effectiveness as in the following example from our own community. The City of Raleigh started its SafeLight program in 2003 (Moss, 2009). In five years the accidents at the intersections with the cameras where down by 83 percent (Bowens, 2008). The existing Red Light cameras are triggered to take a picture of the vehicle by loops under the pavement (Roberts & Wilson, 2003). For locations of existing Red Light cameras see Appendix B, and for controversies see Appendix C.

The maps in Figures 32 and 33 were obtained from Google Maps, 2009. Figure 32 shows a clear layout of the Raleigh, Cary, and Garner areas with the current Red Light

Cameras.

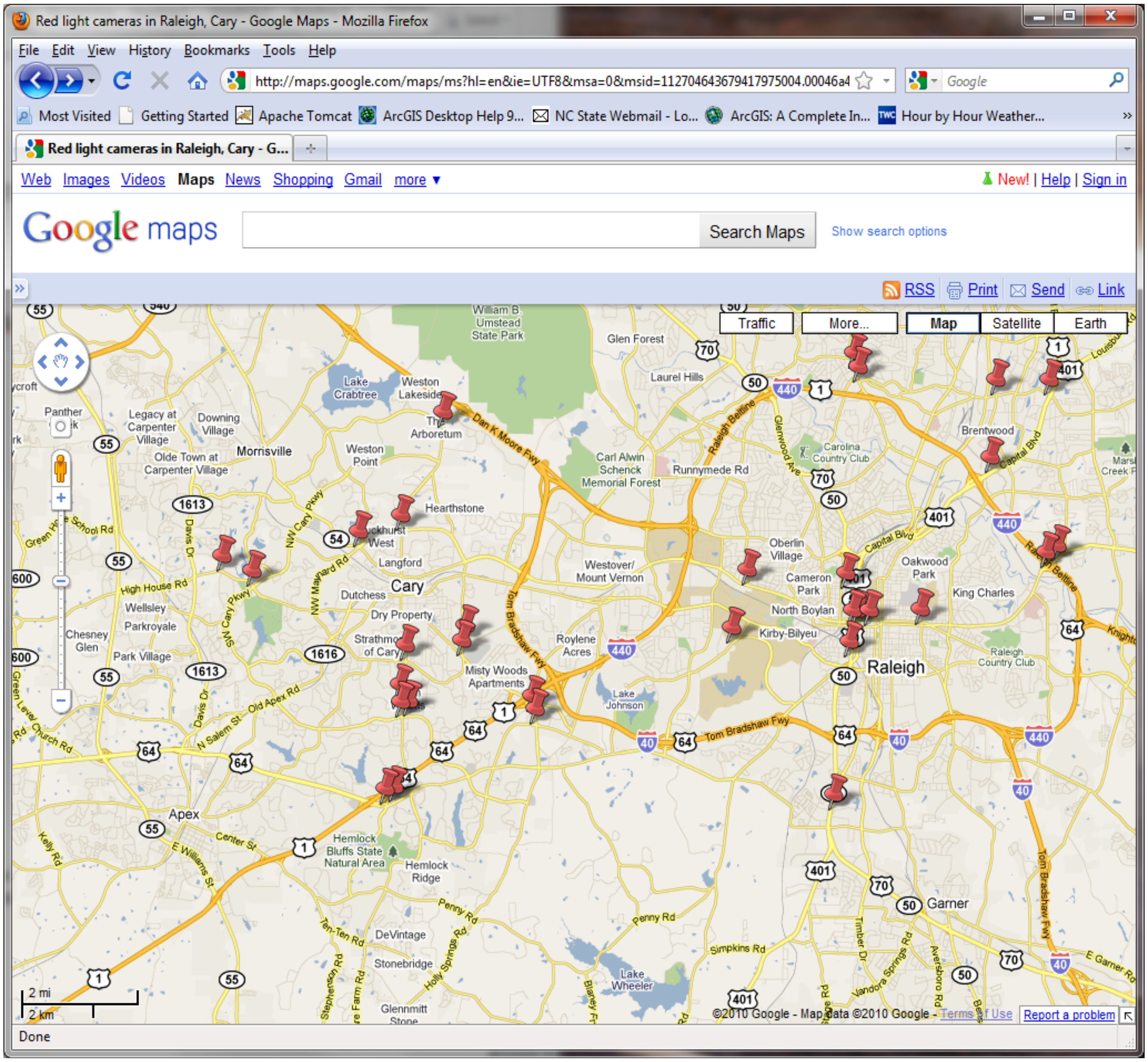


Figure 32. Red Light Camera locations around Raleigh, from Google.com.

Figure 33 focuses on the location of Yates Mill Elementary School.

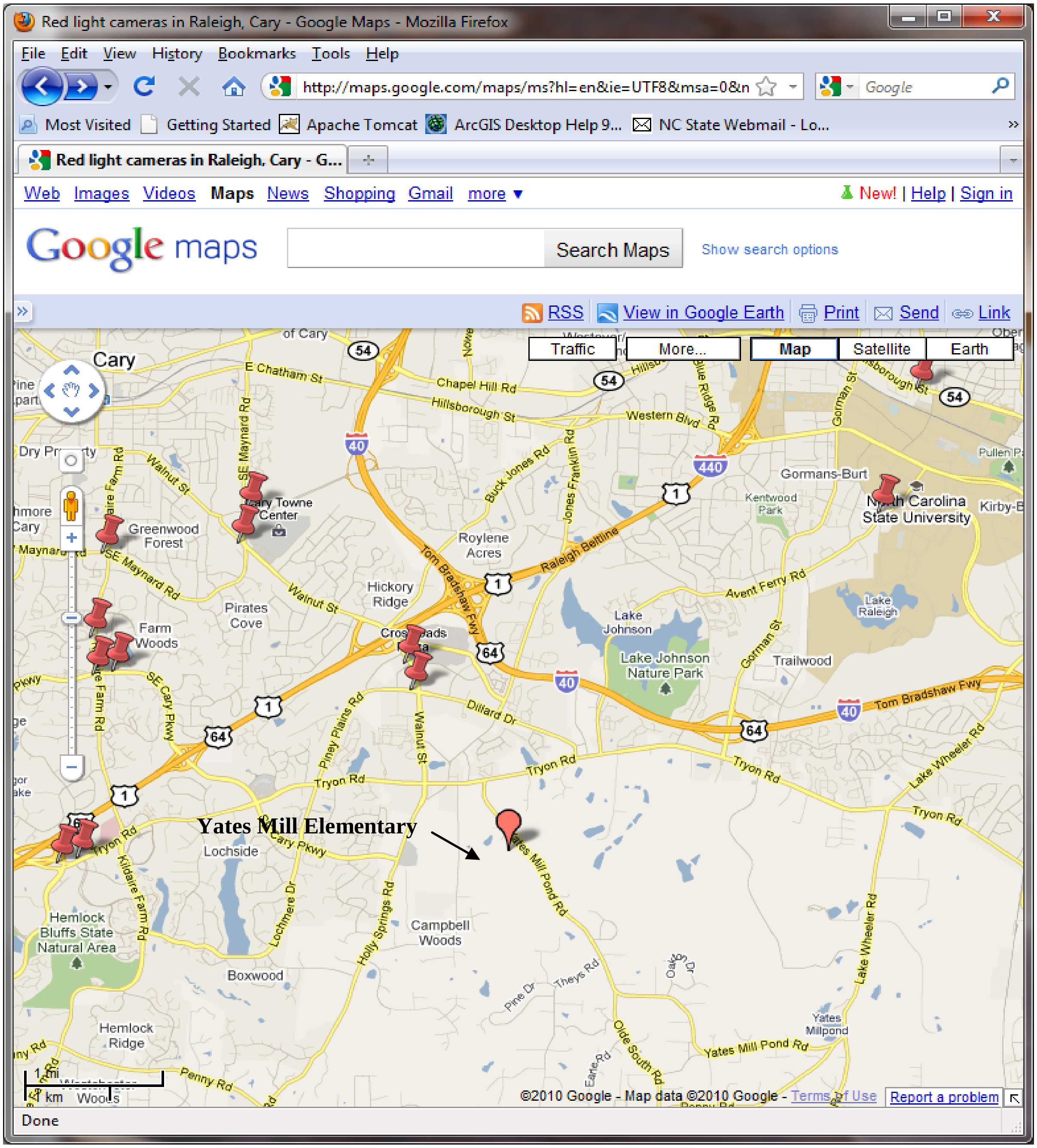


Figure 33. Red Light Camera locations around Yates Mill Elementary, from Google.com.

As can be seen, the desired Red Light cameras labeled with thumb tacks are still too far from the school marked with the red balloon in the center of the map.

Automated License Plate Readers

The Raleigh Police Department (RDP) recently purchased an enhanced camera system called Automated License Plate Readers (ALPR) from PIPS Technology. This technology fits in perfectly with the suggestions presented here, since the photos of the license plates are automatically read and matched with a search database as explained in Myers' 2010 article: Four cameras mounted on patrol vehicles are able to scan and photograph vehicles along with their license plates, even at high speeds. The captured images are then processed and numbers compared to a database of flagged tag numbers. Officers are alerted immediately if a flagged tag number is identified. The alert contains information associated with the license plate including crimes and/or any missing/wanted persons. The date, time, and GPS coordinates are stored in the database along with the captured image of the vehicle and its license plate, for future reference. (p.5)

The center for Missing Children in Raleigh is a small center with only three staff members. This group already has assigned tasks during these emergency situations, such as controlling and processing of the Amber Alert. However, there is a new Raleigh Intelligence Center (RIC) that already houses databases and resources, and processes the information. The group has already helped in a missing child case: "In June while responding to a kidnapping call at an elementary school, the Garner Police Department contacted RIC for assistance in locating a missing child. RIC was able to track down contact information" (Official City, n.d.).

The suggestion made in this thesis to install the traffic-light camera, along with the Automated License Plate Readers to quickly decipher the license plate, joined with the databases and resources at the Raleigh Intelligence Center is a winning combination in the search for a missing child.

FUTURE WORK

It is important to look at the current locations of the Red Light cameras since these may already be helpful in providing useful information. The ability to get access to that data would be ideal on future research work on missing children. As we can see in the following list the only road that was listed on the model and has a red light camera is Tryon Road. It is, however, distant from the desired intersections.

The possibility exists that one of these cameras could have already captured photos of an abductor. This would be an ideal area for future research. It would also be good to investigate in future research if these few cameras may already, as a side effect, be located in higher crime areas. See Appendix B for information on the locations of Red Light Cameras.

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APPENDICES

Appendix A. Detailed Computations

The roadblock is a variable with a unique name per intersection in the road. If it is set to zero, then the delays do not have any time added. If it is set to one, then each intersection on the road will have a delay proportional to the number of cars in the queue times CAR_SEARCH_TIME. It is very important to be aware that **a road_block of one and a CAR_SEARCH_TIME of zero indicates that there is a traffic-light camera at the intersection.** A CAR_SEARCH_TIME > 0 indicates the time to search a car.

- Yates_Tryon_light_delay = Distance_Yates_Mill_Elem_to_Tryon+TRIA(.5,1,2)+TimeExtraTurnLight
- Total_ Yates_Tryon_light_delay = Yates_Tryon_light_delay + Road_Block _Yates_Tryon *CAR_SEARCH_TIME*NQ(Road_Block_Aide_Yates_Tryon)
- Total_Yates_Penny_delay = 2.5+ Road_Block _Yates_Penny *CAR_SEARCH_TIME*NQ(Road_Block_Aide_Yates_Penny)
- Total_Yates_OldSouth_delay = 2+Road_Block_Yates_OldSouth*CAR_SEARCH_TIME*NQ(Road_Block_Aide_Yates_Old)
- Tryon_Jones_light_delay = Distance_Yates_Tryon_to_JonesFranklin+TRIA(.5,1,2)+(2*TimeExtraTurnLight)
- Total_Tryon_Jones_delay = Tryon_Jones_light_delay +Road_Block_Tryon_Jones*CAR_SEARCH_TIME*NQ(Road_Block_Aide_Tryon_Jones)

- Total_Tryon_Dillard_delay = 1.5+Road_Block_Tryon_Dillard*CAR_SEARCH_TIME*NQ(Road_Block_Aide_Tryon_Dillard)
- Total_Penny_Holly_delay = 9+Road_Block_Penny_Holly*CAR_SEARCH_TIME*NQ(Road_Block_Aide_Penny_Holly)
- Total_Penny_Lake_delay = 3+Road_Block_Penny_Lake*CAR_SEARCH_TIME*NQ(Road_Block_Aide_Penny_Lake)

Total_Old_Penny _delay = 2.5+Road_Block _Penny_Old *CAR_SEARCH_TIME*NQ(Road_Block_Aide_Old_Penny)

Appendix B. Red Light Camera Locations in Raleigh and Cary

The locations of the Red Light Cameras in the city of Raleigh and the neighboring town of Cary are:

1. Harrison Avenue and Maynard Road
2. Maynard and Kildaire
3. Walnut Street and Meeting Street
4. Walnut Street and Dillard Drive
5. Rowan Street and East Six Forks Road (southbound)
6. Six Forks Road (northbound) and Dartmouth Road
7. Capital Boulevard (northbound) and New Hope Church Road/Buffaloe Road
8. Brentwood Road and New Hope Church Road (eastbound)
9. Capital Boulevard (northbound) and Highwoods Boulevard
10. New Bern Avenue (eastbound) and North Tarboro Road
11. South Wilmington Street and East Morgan Street
12. South McDowell Street and West Morgan Street
13. South Dawson Street and West Morgan Street
14. North West Street and West Peace Street
15. Avent Ferry Road and Varsity Drive
16. Hillsborough Street and Dixie Trail
17. High House Road an Cary Parkway
18. High House Road and Prestonwood Parkway
19. Tryon Road and Crescent Green Drive

20. Walnut Street and Maynard Road
21. Cary Parkway and High Meadow Drive
22. Kildaire Farm Road and Cary Parkway
23. Cary Towne Boulevard and Convention Drive
24. Weston Parkway and North Harrison Avenue
25. Kildaire Farm Road and High Meadow Drive
26. NC54 and Northwest Maynard Road
27. Tryon Road and Regency Parkway
28. South Dawson Street and West South Street
29. South Wilmington Street and Chapanoke Road
30. New Bern Avenue eastbound at I-440 (inner)

This list was obtained from Google Maps, 2009.

This is a short list compared to the number of sex offenders in the same area, but it is a start.

Appendix C. Controversies over Red Light Cameras

There has been conflict involving the existing Red Light camera programs:

> Rocky Mount, North Carolina decides to stop its red light camera program after court ruling sends profit to school system.
>
> Add Rocky Mount to the growing list of North Carolina cities that have dumped red light cameras after the state's highest court insisted that profit from the devices must be given to the public schools. The city last week decided to allow its contract with Traffipax, a German ticket camera operator, to expire without renewal. Like most North Carolina cities, Rocky Mount was eager to install cameras in September 2002, adding a total of five intersections to the program to ensure a steady stream of revenue. …
>
> This excitement ended in 2007 when the state Supreme Court upheld a ruling that found Article IX, Section 7 of the North Carolina Constitution applied to red light camera tickets. The provision states that "the clear proceeds of all penalties... shall be... used exclusively for maintaining free public schools (North Carolina, 2009).

This type of controversy may have reduced the progress of the Red Light camera programs, but not abolished it. As of June, 2009 both Raleigh and Cary had cameras at 15 intersections (Lamb, et al, 2009). Raleigh has a customer service office staffed with five employees, and issued approximately 19,000 citations from July 1, 2007 to June 30, 2008.

Appendix D. Arena Model of Cell Phone Tower Call Center

This is a model of a Cell Phone Tower Call Center. It is used as a notification system that calls cell phones of holders in the area where a child has been abducted. The cell phones holders may have better visibility of the moving vehicles in the area. Contacting these individuals can generate a clearer picture of the population at the time and location of the event. We built a model of this system, but abandoned it due to the safety concern for the drivers. Also a new law is now in effect to prevent drivers from texting, and in some states it is also in effect for any cell phone use while driving. It would be very difficult to obtain help from the cell phone companies to locate the drivers in the area. Figure 34 displays the model built to represent these actions.

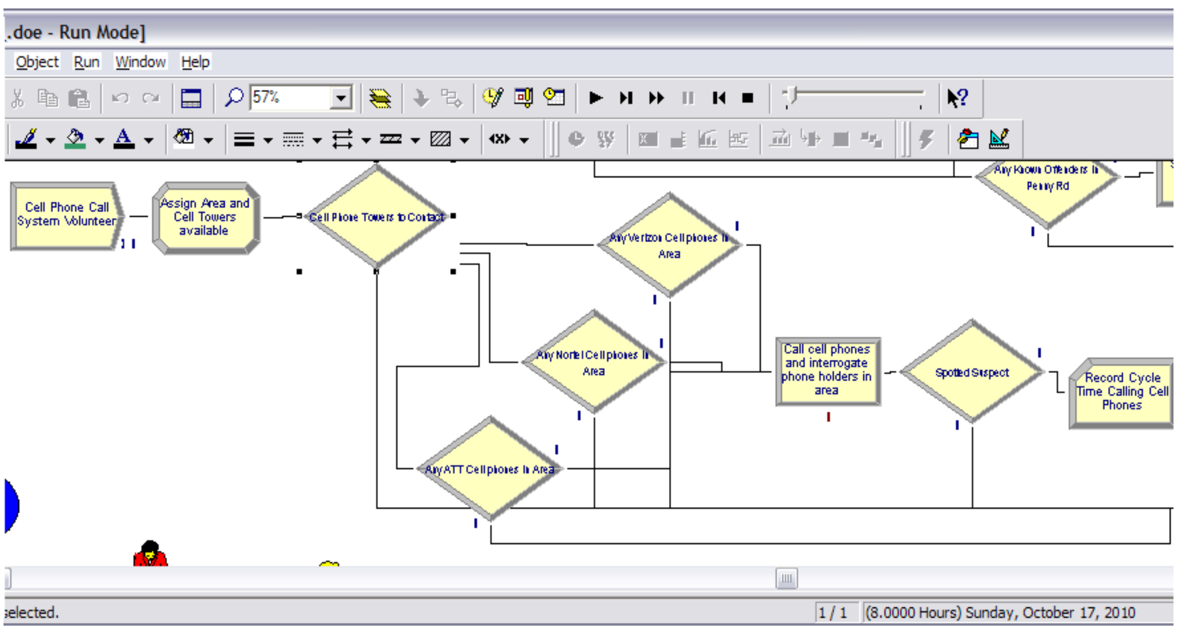

Figure 34. Arena Model of Cell Phone Tower Call Center.

The sequence of steps of the model in Figure 34 follows:

1. The model starts with a Cell Phone Call System Volunteer.
2. The Cell Phone Towers to Available to Contact are assigned as Verizon, Nortel, and AT&T.
3. The volunteer decides which center is closest to the area of abduction to call.
4. The center called decides if there are any of cell phones in the area
5. If there were cell phones in the area then Call cell phones and interrogate phone holders. Perhaps even ask cell owners to take picture of vehicle in front if safe and possible. Otherwise, go to end block, which in Arena is labeled as "Dispose" block.
6. If the suspect is spotted record information, and move to end block.