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A hybrid GIS/in situ analysis of AED coverage on the UNM central campus

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ABSTRACT

Automated External Defibrillators (AED’s) are lifesaving devices that can greatly improve the survival rates of cardiac arrest when used quickly. There are publicly accessible AED’s on the UNM campus, and each device has an effective range based on how quickly a responder can retrieve the AED and return it to the site of the cardiac emergency. The ranges of the AED’s on UNM central campus are analyzed using GIS, interior building measurements, and various retrieval speeds. This helps evaluate the current placement of AED’s on campus and helps reveal where future coverage is needed. This focus on the combined navigation of both interior and exterior spaces creates unique considerations from a geographic theory perspective. Coverage at UNM varies according to the retrieval speed, but using American Heart Association guidelines, less than a quarter (~11-24%) of the exterior space on central campus is covered by an AED.

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I. Introduction

Imagine that you are walking outside on the University of New Mexico campus when you round a corner and find a man lying unresponsive on the ground. A person crouching beside the man points to your companion and says, “You. Call 911.” They point to you. “You. Get me an AED.” Would you know where to go, what to do, how much time you had?

Ventricular fibrillation is a medical emergency that occurs when the electrical activity of the heart becomes uncoordinated and the heart chambers quiver rather than pump productively. In this condition, known as cardiac arrest, oxygenated blood no longer reaches the brain. An electrical shock from an external source has the potential to disrupt the abnormal electrical activity of the heart so that the sinoatrial node, the heart’s natural pacemaker, has a chance to resume a normal rhythm. However, this shock, known as defibrillation, needs to be administered within a very short window of time.

There have been a number of studies performed with the intention of improving the survival rate of out of hospital cardiac arrest (OHCA) in various countries around the globe (Scholten *et al.,* 2011; Nielsen *et al.,* 2013; Moon *et al.,* 2015; Kiyohara *et al.,* 2016). In fact, OHCA is a serious medical concern and a major cause of death in developed countries (Scholten *et al.,* 2011; Nielsen *et al.,* 2013). In many cases, the OHCA’s involve shockable rhythms, and early defibrillation can increase survival rates by a significant percentage: “Survival rates for patients with this abnormal heart rhythm [ventricular fibrillation] can reach up to 50-75% if early CPR and defibrillation are performed within 3-5 min after cardiac arrest. However, patient’s chance of survival decreases approximately 7-10% with every minute delay in defibrillation.” (Scholten *et al.,* 2011: 1273). Early defibrillation is key, occurring as soon as possible after arrest begins, with large decreases in survival rates and survival quality (i.e., the presence of brain damage) for a delay that is measured in seconds and minutes (Scholten *et al.,* 2011; Ringh *et al.,* 2015; Brooks *et al.,* 2016). Due to the negative consequences of this delay, it is imperative in these situations to defibrillate as quickly as possible, even in a timeframe that is often shorter than the response time for emergency medical services (EMS) personnel. To this end, there have been numerous efforts made to increase the involvement of bystander performed defibrillation (Schober *et al.*, 2011; Brooks *et al.*, 2016; Smith *et al.*, 2017; Srinivasan *et al.*, 2017). This is made possible by the automated external defibrillator (AED), a device that allows anyone, even untrained individuals, to assist with a life saving procedure by providing the needed shock to stop the patient's heart fibrillation.

II. Background

Problems with Publicly Accessible AED's

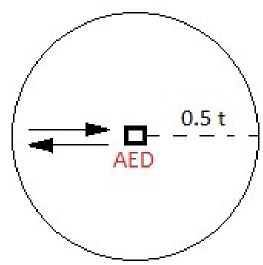
Quick defibrillation with an AED is an important part of OHCA patient care, along with traditional cardiopulmonary resuscitation (CPR) and prompt EMS care. However, the use of AED's by bystanders can remain low in cases of OHCA's (Siddiq, Brooks, and Chan, 2013). There are various reasons for this, including fear and trepidation on the part of the bystander/potential responder, misunderstandings concerning the allowed use of AED's by laypeople, and ignorance about AED's and defibrillation, among others (Schober *et al.*, 2011). One reason for not using an AED in an OHCA is the simple lack of an AED. This particular problem can in turn have numerous causes. There may not be an AED within a practical distance of the OHCA (time is short, and AED retrieval must include the time to reach an AED, the time back, and the necessary time to attach the pads and use the machine), there may be an AED "available" at a nearby location but inaccessible due to an obstacle such as a locked door, there may be a usable AED in the vicinity but the bystander does not know it, or there may be someone with access to an AED who is simply unaware that there is an OHCA occurring near them (Siddiq, Brooks, and Chan, 2013).

Much work has been done to address these problems (Schober *et al.*, 2011; Smith *et al.*, 2017). Educating the public about the importance of AED's, their ease of use (they provide voice commands and will not prompt the responder to deliver a shock unless it is medically indicated), the existence of protections from liability such as Good Samaritan laws, and the fact that often[1] no certification or permission is needed to use them at the time of an OHCA go far in resolving issues of bystanders' hesitancy (Schober *et al.*, 2011). The concerns about having AED's in nearby locations, appropriately situated and spaced so that they can be retrieved quickly, and getting the location information to the people that need it are largely questions of geography.

The Effective Range of an AED

An AED can be thought to have an effective range, as discussed in Siddiq, Brooks, and Chan, (2013), and while these authors use a slightly different definition, as described earlier this range is determined by the time of retrieval and attachment to the patient. Attaching the defibrillation pads to the patient is relatively simple and is a process that can be made faster with training and practice. Therefore, an AED's effective range can largely be determined by the time it would take to get to it and get it back to the OHCA.

Figure 1.



The circle represents the outermost range of the AED, defined by the time (t) required to travel from the perimeter to the center and back to the perimeter.

Perhaps the simplest way of visualizing the effective rage of an AED in a mapping context is to picture a circle with a dot at its center (see Figure 1). The dot represents the AED, and the edge of the circle represents the outer effective limit of its range. In other words, the edge represents the furthest distance from the AED where an OHCA could occur with that AED still being useful. The radius of the circle is determined by the time it would take to travel from the edge of the location of that furthest possible OHCA, to the center and back to the edge. Time and distance are not set in this model, and must be approximated. Time is measured in minutes or seconds and is determined by the quick deterioration of the patient and the onset of brain damage soon after the beginning of the cardiac arrest. The distance is determined by how quickly a bystander can cover this ground within the time that would still give the

1 France and South Korea are examples of two countries where individuals are not allowed to use AED's without training. (Schober *et al.*, 2011).

patient a chance of recovery. To insert values into these approximations, many studies have used values meant to be the distance that the average person can walk or run within a certain time, to include both there and back. The American Heart Association (AHA) has recommended a maximum of 1.5 minutes to reach an AED at a "brisk walk" in an AED program area (Aufderheide *et al.*, 2006: 1262). One study in Toronto, although the 360 degree nature of the ranges was implied, tested for its effective ranges 10 meter intervals between 10 and 300m (Siddiq, Brooks, and Chan, 2013). A distance of 100m was used in another Toronto study (Chan *et al.*, 2013), which the authors estimated was the maximum distance a bystander could cover within the AHA's 1.5 minutes (1803). Some of the studies using smart phones to alert potential responders, while not discussing the concept of an effective range explicitly, used varying distances as criteria of whether to send the AED location to the responder, such as 400m (Brooks *et al.*, 2016) and user defined intervals of 100, 200, 500, 1000, and 1500 meters (Sakai *et al.*, 2011).

The circle model is not perfect. In reality, moving in different directions from the center may take more time than other directions (as flights of stairs must be climbed, for example). Other directions may not be possible at all (like if there is a wall). This may change the circle to a more amorphous shape. The circle is good for a beginning conceptualization, but negotiating real world terrain quickly changes the effective range of an AED.

Mapping and Situating AED's

When multiple AED's are in question, an optimization problem arises of how to best situate the AED's to give the maximum coverage of a given area. Changing the radii of the circles can change how much the circles overlap. Barriers in the area in question such as the stairs example above, or any number of obstacles in the real world that can slow a responder down can change the effective range of the AED's. Time can be more of an issue, as buildings with publicly accessible AED's may close and lock their doors after a given hour (Sun *et al.*, 2016).

These different scenarios can be mapped with a geographic information system software. Different maps can be developed to represent coverage with varying coverage areas. Maps can also be made to show the difference in coverage for different times of the day and night. And to optimize the AED coverage of a given area, geographic theory and mathematical models can be used, such as the one proposed with the Maximal Covering Location Problem (Church and ReVelle, 1974) or the modified version used for AED's (Chan *et al.,* 2013). Before working to improve AED coverage however, it is worthwhile to take stock of their current placement and coverage of an area.

New Mexico and Heart Disease

New Mexico, like the United States as a whole, suffers from heart disease as a leading cause of death. For example, for the years 2010 to 2015, heart disease was a leading cause of death in New Mexico, ranking second after cancer for all of the years except 2011, when it ranked as the number one cause of death in the state (Vital Reports n.d.).

As an urban university in the largest city in the state, assessing the distribution of AED's on the University of New Mexico campus is a relevant and potentially lifesaving endeavor. A university campus is also a unique place to study the accessibility of AED's as most of the buildings are public, and much of the campus is traversed more easily by foot than by car, increasing the potential for the type of pedestrian bystander OHCA scenarios described thus far. Furthermore, a distribution of AED's already exists on campus, and possible shortfalls between the current array and an optimized one may not be as expensive and difficult to implement, as it would be starting from scratch.

While there have been a number of studies on publicly accessible defibrillators, or PAD's, studies that specifically look at them on college campuses are rare. Also, it is not known of any study of AED coverage that examines both the exterior environment, the purview of GIS, while taking into account the time cost of interior travel through the buildings where the AED's are stored.

III. Research question

Using the American Heart Association's 1.5 minute one-way retrieval time guideline, how many AED's are accessible from any given exterior 10 foot by 10 foot area on the University of New Mexico central campus, and how does total exterior coverage present as a percentage of total area?

IV. Literature review

Generally, the literature for this paper is concerned with the topic of geographic access, especially geographic access of medical services and facilities. Studies that make up this body of literature are numerous and diverse, containing for example studies of population travel time and distance to hospitals for the patient (Bosanac *et al*., 1976; Yamashita and Kunkel, 2010; Delamatar *et al*., 2012) or travel to the patient, such as by EMS (Peleg and Pliskin, 2004).

More specifically, the literature review for this paper falls roughly into three categories. There are papers of studies concerned primarily with topics related to public access defibrillators (PAD's), which are AED's situated in public places and are meant to be used by the public. One of the most common topics in this area is the effective distribution of such PAD's to cover wide areas. Another category of studies is the use of GIS to analyze the occurrence of OHCA in various (usually urban) locations, and/or the mapping of the locations of registered AED's in these locations. A third category is concerned with the use of different means of alerting registered users of different programs the location of an OHCA incident, and often the location of the nearest AED as well. These programs have largely been used with smart phones, and alert the volunteer responder via an app or text message.

Publicly accessible defibrillators

Perhaps the best way to begin a discussion of PAD's is by reviewing a study of how well their intended users, members of the general public, are familiar with them. This study took place in the Netherlands, and can not be used to gauge how well the public in other areas is informed about AED's, but it does provide some insight into how well acquainted a cross section of travelers in Europe were familiar with the concept (Schober *et al.,* 2011). In this study, the authors conducted questionnaires in the Central Railway Station in Amsterdam. Open ended questions were used to evaluate recognition of AED's and the willingness to use them. "Of 1,018 subjects, only 47% recognized an AED and only 47% were willing to use it" (241). When the survival rates of OHCA are low anyway, adding a large reluctance on the public's part to use AED's greatly exacerbates the problem. As stated earlier, this study done in 2011 cannot be used to interpret the knowledge of AED's of people in other areas. However, it is concerning that more than ten years into the 21st century, more than half of the people asked in a large city in a developed nation did not know what an AED was. This perhaps emphasizes the need to not assume that merely placing AED's in public areas is sufficient to increase OHCA survival rates.

Much of the PAD research has been done in large cities, large areas of countries, or entire countries. In Sweden, Ringh *et al.,* (2015) conducted a study of a PAD program implementation for Stockholm. This study is of interest because the authors looked at both a coordinated approach to the creation of a PAD program, as well as the effects on patient survival from the use of unregulated or unregistered AED's. In PAD programs, AED's are very often registered, which is to say that their location and availability information is given to some third party, most often an emergency dispatcher or dispatch organization. This registration very often takes place upon the purchase of an AED by an individual or a company, and is encouraged to make the AED more useful by advertising its existence. In the Swedish study, the authors concluded that having PAD's of any kind, regulated or not, increased the use of AED's by bystanders and increased OHCA survival rates, but they also felt that the regulated approach was more efficient (Ringh *et al.,* 2015). In Denmark, a private foundation set up a website where purchased AED's could be voluntarily registered, and that information is now accessible by emergency dispatchers across the country (Nielsen *et al.,* 2013). In Japan, a two year study was conducted to see how often PAD's were actually used in cases of OHCA in Osaka Prefecture (Kiyohara *et al.*, 2016). Their findings of how many times AED pads were actually applied to patients may be surprisingly low. Out of an initial 15,277 OCHA's in the study period, 9,978 OHCA's were included in the study, and of these only 351 (3.5%) had defibrillation pads applied to the patient by a bystander (Kiyohara *et al.*, 2016). This illustrates that while there is increasing interest in PAD's (the same study points out that there were more than 500,000 AED's in Japan in 2013, although compared to the country's population for the same year that is a small number), more needs to be done to get people to use them.

Also conducted in Osaka was a study to try out a newly created cell phone map to locate the nearest AED's in a simulation on the campus of Kyoto University (Sakai *et al.*, 2011). The study was conducted in 2009, and already the technology used (flip-style cellphones) is dated, but this was an early look at using the mobile computer aspect of cellphones to get lifesaving information to OHCA bystanders. The researchers took two groups of 22 and 21 participants unfamiliar with the setting and ran them through a simulation of an OHCA, where they were asked to retrieve the nearest AED. One group acted as a control and the other was given the cellphone AED map. The authors of the paper found that while the map succeeded in reducing the straight line distance traveled to retrieve the nearest AED, the time to do so was not significantly reduced from the control group. The authors felt that this was probably due to the time taken to use the map, to find the participant's location, and to orient themselves. The study included a follow up questionnaire, and one thing that the participants from both groups found helpful were the preexisting signs designating the location of AED's installed on campus.

Signs for AED's, while helpful to show the location of PAD's, are often not particularly encouraging to the lay bystander. Smith *et al* pointed out in their study in the UK that the lightning bolt symbol resembles warnings of high voltage shock danger (Smith *et al.*, 2017). They further note that the signs were developed without any input from the potential users of the AED's, and in a survey conducted before their research, only 39% recognized the ILCOR AED sign. The ILCOR is the International Liaison Committee On Resuscitation, and the AED sign in question is meant to be a universal symbol. However, after two surveys with close to 2,000 participants, the researchers in this study found that people greatly preferred a “heart-trace” symbol to a lightning bolt. The heart-trace symbol is a recognizable section of an electrocardiograph superimposed over a heart icon. Also, people preferred non-medical and non-technical terminology: “heart re-starter” was preferred to any conventional term involving “defibrillator” (Smith *et al.,* 2017). This research should not be ignored. Anything that can increase bystander use of AED’s, even details that might not seem very important, should be considered carefully.

Optimizing PAD placement

A study was done in Phoenix to compare the sites of OHCA’s with PAD locations (Moon *et al.*, 2015). This study also moves more into the realm of using GIS to study PAD’s and was intended to help organize PAD placement. Data from Save Hearts in Arizona Registry and Education (SHARE) AED registry was layered in a kernel density map with OHCA location data to see where AED’s were located with respect to OHCA hotspots. The authors concluded that there was poor correlation with locations of historical OHCA incidents and the placement of PAD’s. They also found areas with high incidents of OHCA’s and poor AED coverage. The authors also pointed out that the location types with frequent OHCA incidents do not stay the same from one community to the next. Another study in Toronto (Brooks *et al.,* 2013) found that most OHCA’s occurred in retail locations, where in Phoenix researchers found that most OHCA’s occurred in areas relating to cars: in vehicles themselves, and in parking lots and on roads (Moon *et al.,* 2015). This demonstrates the need for communities to perform their own analysis when it comes to PAD placement.

Sun *et al.* (2016) took temporal access into account in another Toronto study. They make a compelling argument that this needs to be done, as using spatial optimization alone can lead to great overestimations of the area of PAD coverage, as PAD's thought to be available for an area become inaccessible after hours or on weekends. This time of decreased coverage coincided, in Toronto at least, with an increase in the number of historical OHCA's. This may not be the case in other areas, as part of the off-hour coverage was hypothesized to be exacerbated by zoning characteristics unique to this city. However, a coverage loss as high as 31.6% for off-hours in this example demonstrates the importance of this issue.

As stated earlier, while there are many studies of publicly accessible defibrillators, studies that specifically look at PAD's on college campuses are rare. In addition to the Sakai *et al.,* (2011) study mentioned above, in which the setting of Kyoto University was largely incidental, a study at the University of Virginia is a review of the process of creating a PAD program on that campus, with the intention of making it easier for other institutions to develop similar programs (Whitney-Cashio *et al.,* 2012). To create a PAD program means to install AED sites at a location in a studied manner and facilitate the maintenance and coordinated use of the AED's. One interesting point that the authors make, referring to an earlier study (Stiell *et al.,* 2004), is that the basic life support procedures discussed in this paper, such as AED use, CPR, and activation of EMS, can be more effective than advanced lifesaving techniques that are brought out of the hospital setting, such as medications and airways. Similar results were seen in another study (Mitchell *et al.* 1997). This reinforces the importance of having a strong PAD program on the UNM campus.

Whitney-Cashio *et al* (2012) stress the importance of having institutional leadership involved in the program, as well as having the necessary personnel, which they list as a "medical coordinator, program coordinator, local site AED coordinators, and CPR/AED training facilitator" (e5). Creating a new, or reinforcing the existing, PAD program for UNM is beyond the scope of the proposed research for this project, but the results of this paper could help the above-mentioned individuals if changes are made to the way the current AED's are administered. Two of the steps or phases of the PAD program in the University of Virginia study overlap with the aims of this thesis project. The study by Whitney-Cashio *et al*. (2012) accounted for preexisting AED's on the UVA campus and identified priority locations that were not already covered.

Creating a model that demonstrates the effective range of the AED's on campus while taking into account the neglected consideration of interior travel time is the goal of this paper. An assessment of current campus AED coverage is an essential first step towards achieving an optimal placement of AED's and an efficient OHCA response program at UNM.

V. Methods

Study Area

The study area for this project was the majority of the University of New Mexico main campus. Due to private property interspersed with that of campus in the northwest corner, and with the relative lack of public buildings in this section (with the exception of the John and June Perovich Business Center that is well covered with two AED's), it was decided to not include the area of central campus north of Las Lomas and west of Yale Boulevard. Likewise, the area in the northeast bound by Stanford Road NE and the boulevards Lomas, Vassar, and Campus, was not included. This area mostly consists of a large parking structure (which is not without the threat of OHCA's: see Moon *et al*., 2015) and one non-public AED. The north side of the street of Las Lomas between Yale Blvd and Stanford Blvd NE was included, as this is an area of unbroken campus property with pedestrian traffic and publicly accessible AED's.

The area included in the study therefore was the part of central campus bound by University Blvd, Las Lomas, Girard Blvd, and Central Ave, as well as the stretch on the north side of Las Lomas as described above (see Figure 2).

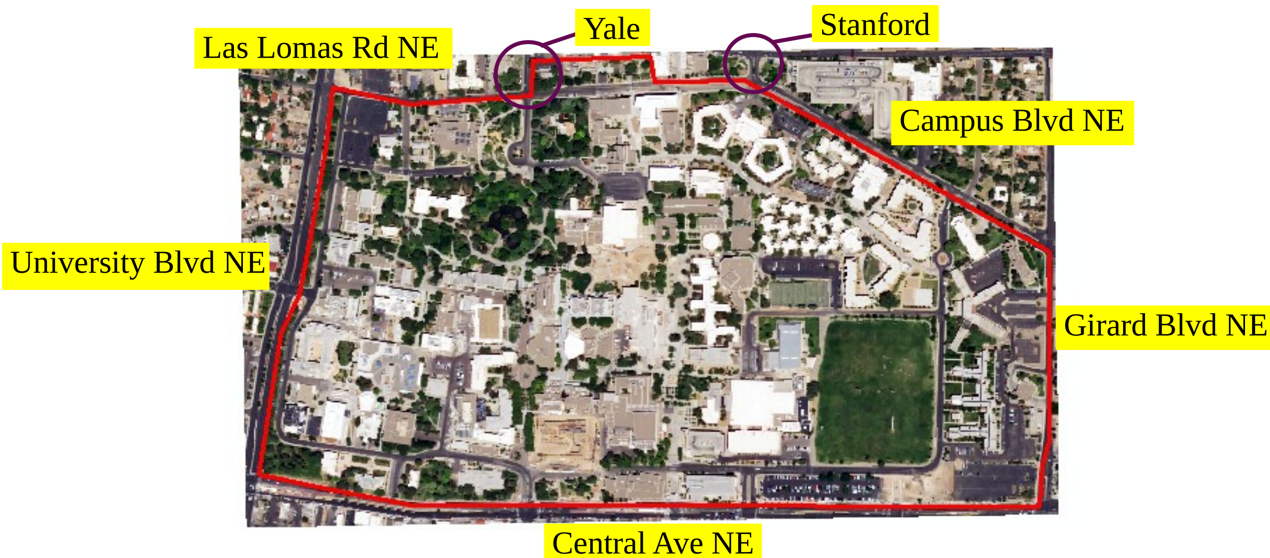


Figure 2. Aerial photograph with the study area outlined in red

Data Collection

The core question of this thesis poses some unique geographical considerations. Rather than merely using a GIS accessibility model in an outdoor setting, the situation of an OHCA on campus requires that both interior as well as exterior environments be evaluated because AED's are typically stored inside, and an OHCA can occur anywhere. In addition to this, the strict time constraints and the subsequent greater importance of obstacles on the ground require more information than mere Euclidean distance.

The interior aspect also poses some challenges to data collection. GPS can not be used to retrieve the coordinates of an AED located on campus, since GPS satellite acquisition within buildings is unreliable. GIS analysis of exterior[2] travel time on the other hand uses a coordinate system. Therefore, to get the complete picture of AED retrieval in an emergency on the UNM campus, a hybrid GIS/*in situ* data collection process needed to be created.

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2 Exterior is a word used in this paper in the sense of "out of doors," and is not to be confused with the external "E" in AED, automated external defibrillator, which refers to being applied to the outside of the body: the skin of the patient's thorax.

With help with the campus AED coordinator, a spreadsheet with approximate AED locations (building names, floors, room numbers) and on-site facilitator contact information was obtained. These locations were then visited to get eyes-on the AED's in most cases, and often pictures were taken. Once an AED location within the building was known, a rough sketch was made of the floor plan for the building, often using the fire escape plan schematic as a guide. These were used to facilitate note taking, and were not to scale or architecturally precise. Once they were obtained, interior distances were measured from the AED to each of the building's entrances, with some exceptions. Doors with restrictions, such as Emergency Exit Only, or barriers to travel such as locks or blocked passages, were not included. Non-public doors such as loading docks or doors that entered into restricted areas were generally not considered.

While an OHCA is certainly considered an emergency, the Emergency Exit Only doors were not included because these doors on campus often lack an exterior handle, and are strictly one way. Not only were these doors problematic from a data collection aspect, they were also assumed to be of unlikely use in most OHCA scenarios unless they offer a significant shortcut on the return trip. This could be the case but such scenarios were not included in this analysis. It is assumed in this model that the return trip will follow the route of the initial one in reverse.

Interior distances were measured by pacing. Although low tech, pacing offered the advantages of being easy, requiring no equipment, and quick, which was a consideration given how many routes per building needed to be measured. Several routes were repeated, and average distances for travel were calculated. Stair pacing was done by skipping a step on both up and downstairs travel, which was closer to the flat surface pacing measurement in terms of horizontal distance. In the case of double doors (very common on campus) the exterior door was always used for the measurement reference.

Once the interior distances were measured, these needed to be related to the outside environment. Coordinates of building entrances[3] were taken using a Garmin eTrex 20x handheld GPS device in Degrees Decimal Minutes (DDM) format. However, in the majority of cases, these entrances were recessed under a roof or building façade where accurate GPS coordinates could not be taken. Therefore, coordinates were taken back away from the building, where satellite communication could be clearly achieved, and the distance between the coordinate point and the actual entrance was measured, again by pacing. This paced distance was later added to the interior distance previously recorded. Thus a sort of halo of coordinates around a building was created, representing the building entrances, with a transitional exterior/interior distance added to the actual interior measurements. Generally coordinates were taken facing the door head on, looking perpendicularly to the building exterior. This sometimes varied according to the situation on the ground, as the logical approach to a door might be dictated in a more oblique fashion due to walkways, railings, etc.

For this analysis, campus was assumed to be a flat surface. This is of course not the case, but it was felt to be a reasonable assumption since there are not really elevation changes on the central campus that would result in an a radically different overland travel time. Perhaps the greatest elevation change is between the plaza in front of Zimmerman Library and the plaza to the north and east of the SUB.

GIS Analysis

General process

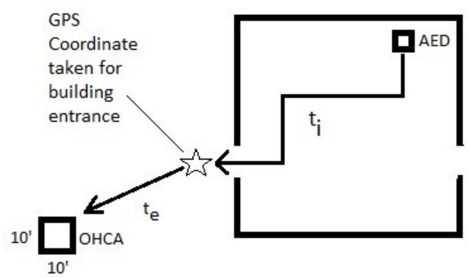
After the *in situ* measurements were taken, the analysis shifted to using the GIS. Using ArcGIS and a shapefile obtained from the city courtesy of the Earth Data Analysis Center (EDAC), a raster layer of central campus was created excluding building footprints and barriers such as walls and the Duckpond,

3 “Entrance” and “exit” will be used interchangeably in this paper. As in the real world, the distinction in the model resides in the direction of travel. In this case the same door is being considered for entering as well as exiting.

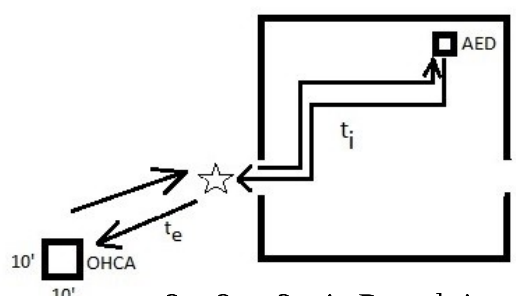
with a resolution of 10'x10'. The projected coordinate system WGS 1984 World Mercator was used, which has meters as units. Barriers were coded as NODATA. Pixels representing areas on campus where one could walk freely were assigned a value of 1. This was the initial surface against which the area extent of external AED coverage was evaluated. The ultimate goal was that each pixel would have a value that corresponded to the number of nearby AED's that fell within the American Heart Association's 1.5-minute one-way retrieval guidelines (see Aufderheide *et al.,* 2006). As previously discussed, these time constraints would have to include interior travel time.

To determine which exterior pixels were covered by a particular interior AED, the travel time from the AED to an exit was calculated using the interior distance measurements and varying average speeds determined by different scenarios. This interior travel time (t_i) was subtracted from the 1.5 minute one way maximum time from OHCA to AED. The result of this subtraction was then used with ArcGIS to determine which pixels were to be included within the travel distance defined by this remaining (exterior) travel time (t_e) (see Figure 3).

Figure 3.



t_e found by 1.5min-t_i and
$t_e+t_i \leq 1.5$ min



$2t_e+2t_i \leq 3$ min Roundtrip between OHCA and AED

In other words, the pixels that were covered by a particular AED with a given retrieval speed were found with the equation:

$$1.5\text{min}-t_i=t_e$$

This insures that the pixel, representing a 10'x10' area of campus, is within the one-way travel time of 1.5 minutes ($t_e+t_i \leq 1.5$ min), and the entire round trip from the OHCA to the AED and back is within 3 minutes ($2t_e+2t_i \leq 3$ min).

The distance between the furthest included pixel and the entrance coordinate point was the exterior range (R_e) of the AED.

The Cost Distance tool in ArcMap was then used to map the R_e of an AED from all available building entrances to determine the total number of pixels in all directions that were covered by that AED, taking barriers into consideration. The individual entrance/exit point was the input feature and the previously described campus surface was the input cost raster. All important to this analysis was the maximum distance input field, which defined the extent of the R_e in meters. With this tool the exterior surface area surrounding an AED, in 10’x10’ sections, was evaluated as to whether from this space a person responding to an OHCA could run to the AED and back within 3 minutes (1.5 minutes one way). In the real world this would mean running from a particular point on campus where an OHCA was occurring to a building where a AED was located, entering the building, retrieving the AED, and returning to the site of the OHCA.

This process was repeated for all exits (exceptions noted above) of a building containing an AED, and was also repeated for buildings with multiple AED’s. In practice, the internal distances were tallied with the help of the hand drawn maps for different routes through the buildings from the AED’s to all the exits. The number of paces was recorded in a spreadsheet, and using 2.5 feet per pace, the time of one way retrieval as well as the exterior effective range of the AED for a particular exit was calculated in both feet and meters using the following:

Speed: (a mi/hr)(5280ft/mi)(1hr/60min)(1min/60sec) = b ft/sec

t_i = (c paces)(2.5 ft/pace)(1 sec/b ft) = d sec

t_e = (90 sec – t_i)

R_e = (t_e * b ft/sec for t_e > 0) * 1m/3.281ft

The number of paces for an AED to exit distance never changed, while speed was something that could vary. Different speeds were therefore entered into the spreadsheet and the resulting R_e values were entered as the maximum distance in the Cost Distance tool in ArcMap. This was done for each exit coordinate for 2, 3, 5, 7, and 10 mph. On the lower end, 2 and 3 mph were representations of average walking speed, while 7mph was considered a fast run considering factors such as pedestrian traffic and other hinderances. Of the remaining two, 10 mph was felt to be unrealistic but was used to illustrate a best possible coverage scenario, while 5 mph was thought to be perhaps the most realistic: a OHCA responder in a hurry but negotiating obstacles. After getting a general idea of the coverage under a 10 mph scenario, this extreme speed was not taken through the subsequent analysis.

Specific steps

Base Raster Layer Creation

As mentioned above, a shapefile of Bernalillo County with digitized building footprints was obtained with the help of EDAC. This shapefile was cropped in ArcMap to correspond with the study area. To the existing building footprints were added digitizations of barriers on campus that would impede or reroute foot travel, such as walls, fences, fountains, the Duck Pond, etc. A polygon was then drawn around this portion of central campus to define the study area. The Polygon to Raster tool was then used to create a friction surface, with areas on campus where a person could walk freely on campus given a value of 1 and barriers receiving a value of 0 (Figure 4). The coordinate system and pixel size were defined in this step. The Reclassify tool was later used to change the 0 pixel values to NODATA for the friction surface.

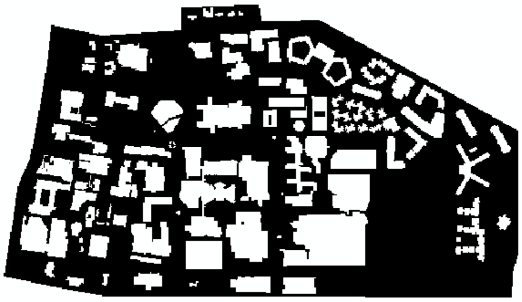


Figure 4.

The friction surface of central campus shown in black, with building footprints and other barriers shown in white.

The black surface represents exterior campus areas where a person can walk.

Exit Coordinates

The exit coordinates were then added as point shapefiles to the map to represent the entrances of buildings with AED's (Figure 5). Since a building might have one AED but many entrances, there were more points than AED's on campus. In order to insure that ArcMap was referencing the correct point for the cost distance step, each point was created as a separate layer.

Figure 5.

The friction surface with the points representing the exit coordinates added.

Cost Distance

The Cost Distance tool was then used to map the R_e of the AED's for each exit. The point shapefile for the particular entrance was the feature source data, while the friction surface was the input cost raster. The maximum distance (in meters) determined the extent of the desired raster, and was as previously explained dependent on the given retrieval speed, calculated by the above equations, and generated for each point with the help of a spreadsheet. Due to the varying distances in a building from the AED(s) to the entrances, each interior distance produced a unique exterior range for each entrance/exit, which changed with each speed. Therefore the Cost Distance tool had to be used individually for each coordinate and for every speed scenario (Figure 6).

Figure 6.

The Cost Distance rasters for areas defined by a 2mph retrieval speed. The varying colors represent graduated distances from the entrance and therefore the AED.

Raster Calculator Step 1

After the general shape of R_e was determined with the Cost Distance tool, the values obtained needed to be converted into boolean 1's and 0's to perform the necessary raster arithmetic. This was achieved using the Raster Calculator and Reclassify tools. The Raster Calculator step was very simple but needed to be done for each Cost Distance raster. The equation used was Cost Distance Raster ≤ Maximum Distance. This step converted the gradient values obtained from the Cost Distance tool into 1 and NODATA values. NODATA were areas outside the reach of the AED, while 1's were covered.

Reclassify

The Reclassify tool was then used to convert the NODATA values from the previous step into 0's so that further raster calculation could be performed.

Raster Calculator Step 2

At this point, the R_e was visible for each building exit and the pixel values were in the proper form, but each raster was an independent entity. For a single AED therefore it was common for there to be overlap between neighboring rasters if R_e values were large enough and/or different entrances were close enough to each other. If these rasters were left independent, multiple overlapping R_e rasters could be misinterpreted as being an area covered by multiple AED's when in fact the area was instead covered by one AED accessible by multiple entrances. To avoid over counting AED's, these separate rasters needed to be combined. This was done with the Raster Calculator Union function (Figure 7). Care was taken to combine rasters that corresponded to the same AED, and not to merely combine all rasters associated with a particular building, as some buildings have more than one AED.

Figure 7.

The R_e shapes after all of the rasters for each AED had been consolidated.

The different colors denote different AED's. There are areas of overlap but they are difficult to completely visualize at this stage.

Raster Calculator Step 3

Now that there was a raster for each AED, the extent of overlap needed to be seen clearly. In order to achieve this, the rasters were added together with the simple addition feature in the Raster Calculator tool (Figure 8).

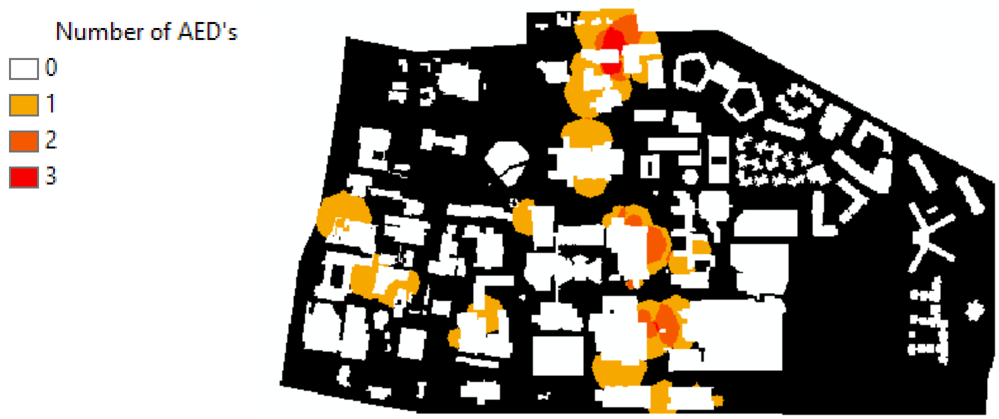


Figure 8.

The final image of AED coverage with a 2mph retrieval speed. The more red areas have coverage from more AED’s. The numbers in the color scale to the left indicate the number of accessible AED’s.

VI. Results

Tables 2-6 in the subsequent pages show the distance and exterior range data for the building exits and for the different retrieval speeds modeled. The following key explains the building abbreviations used (see Table 1). “EX” refers to an exit. In some cases there was only one exit and the EX was left off. In other cases the exits were going to be numbered but it was decided to use only one, as in the case of the Johnson Center, which only has one main entrance. Sometimes there were insufficient data in regards to interior measurements to include an exit. Such exits will be listed below (see Figure 9). In the case of Pope Joy Hall, the floor plan is so open that not all possible interior routes were thought of at the time of data collection, and calculations were performed to arrive at the route lengths. These cases were highlighted yellow to show that they were not directly measured.

Figure 9.

Building exits with insufficient (I.D.) or no data (N.D.)

CAST EX9	N.D.
CLINIC	N.D.
MVH WCOURT2 EX2	I.D.
MVH/ADV COURT EX2	I.D.
ORTEGA EX3	I.D.
PJOY EX3 to AED1	I.D.
PJOY EX5 to AED1	I.D.
PJOY EX2 to AED2	I.D.
PJOY EX5 to AED2	I.D.
PJOY EX6 to AED2	I.D.
PJOY EX4 to AED3	I.D.
PJOY EX5 to AED3	I.D.
PJOY EX6 to AED3	I.D.

Table 1. Building Abbreviations

Abbreviation	Building Name	UNM Map Building Number
ADV EAST EX	University Advising and Enrichment Center (East side)	85
CAST	Castetter Hall	21
ECE	Electrical and Computer Engineering/Centennial Library	46
ECON	Economics	57
GPH	George Pearl Hall	195
GSM	Anderson Graduate School of Mgmt/Parish Library	87
JOHN CTR	Johnson Center	59
McKINN	McKinnon Center for Management	unknown
MVH	Mesa Vista Hall	56
ORTEGA	Ortega Hall	79
PJOY	Popejoy Hall (Center for the Arts)	62
SUB	Student Union Building	60
ZIM	Zimmerman Library	53

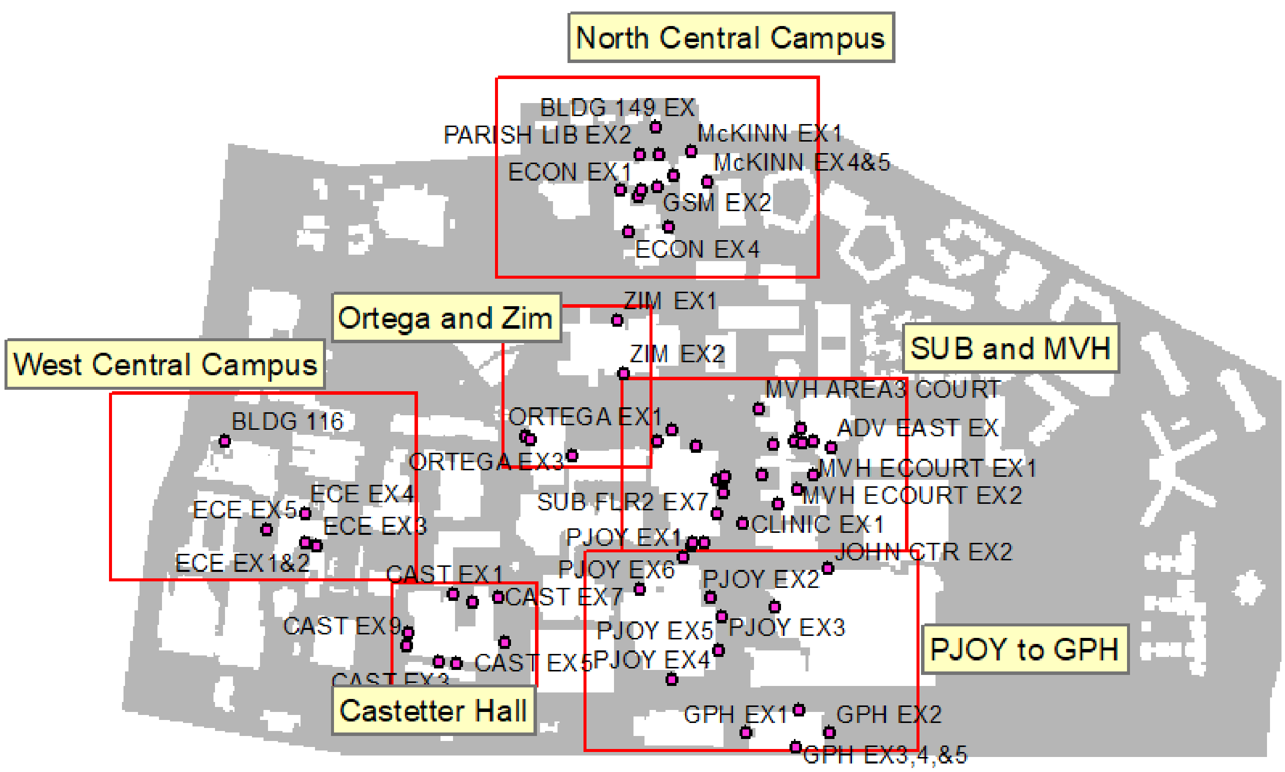
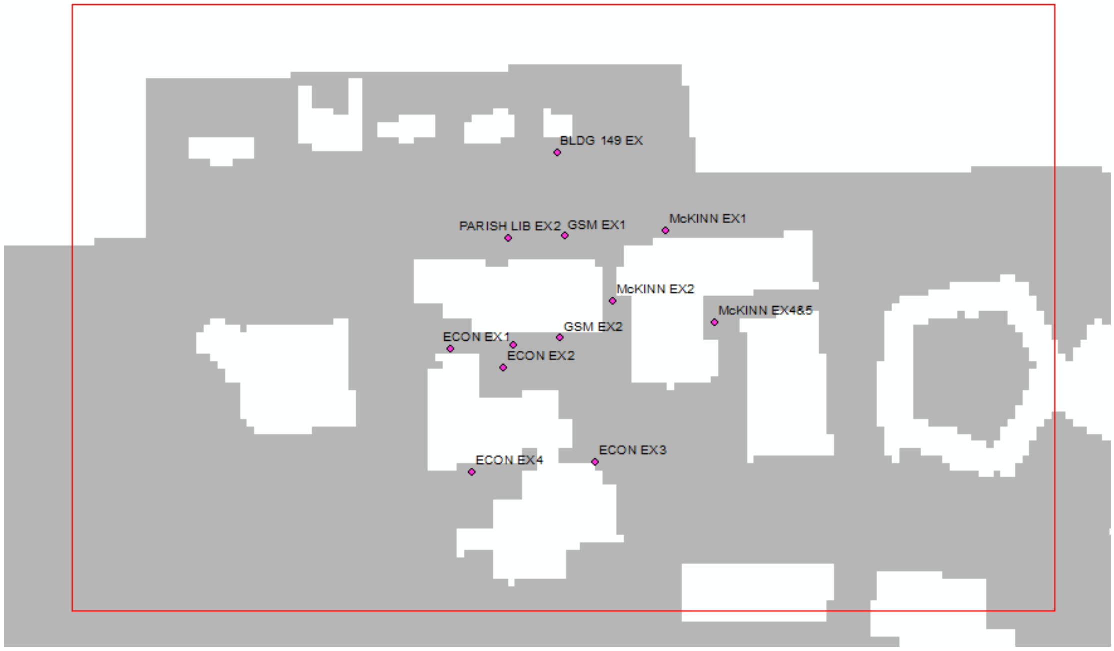


Figure 10. The exit coordinates used. Figures 11, 12, and 13 show blow ups of the areas outlined in red.



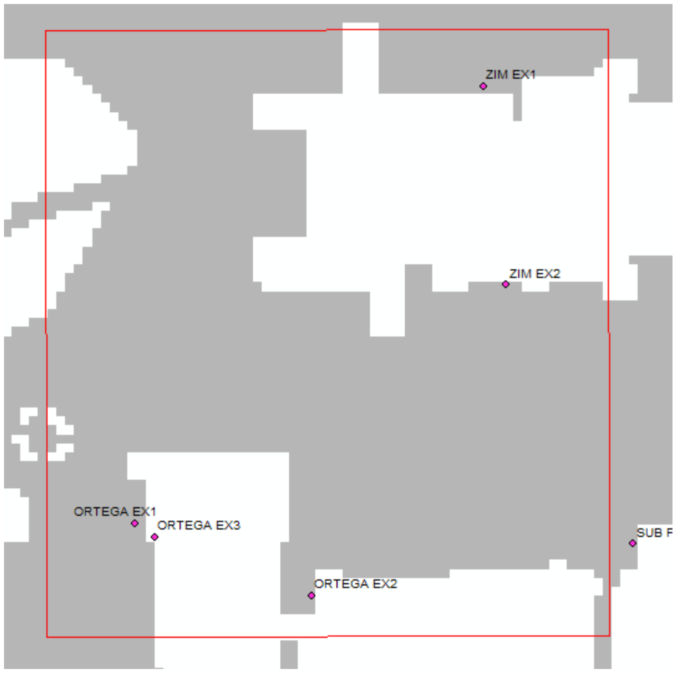
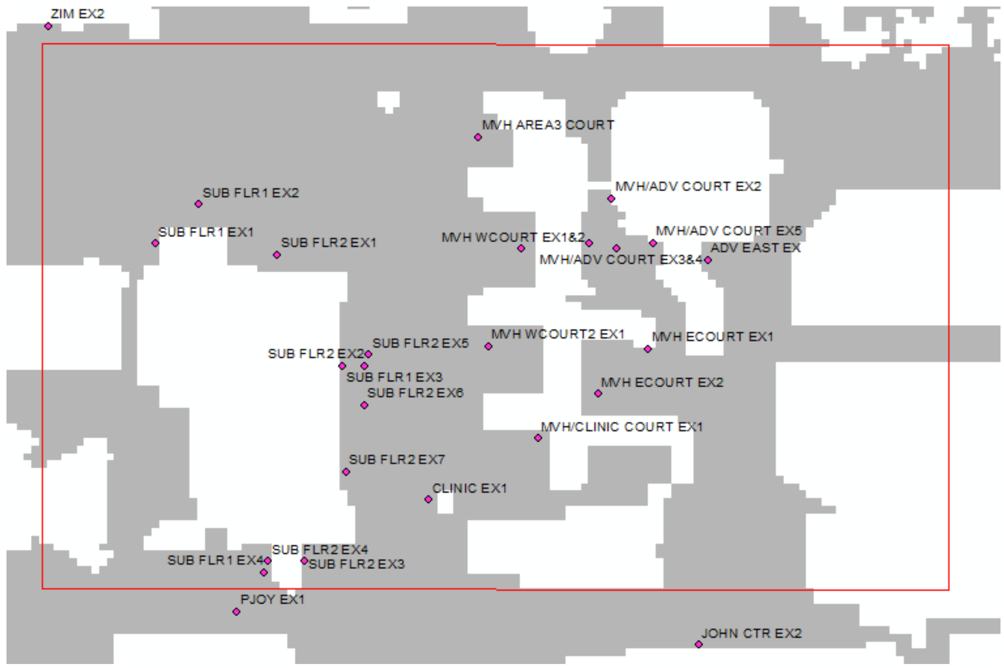


Figure 11.

Top: North Central Campus

Bottom: Ortega and Zimmerman



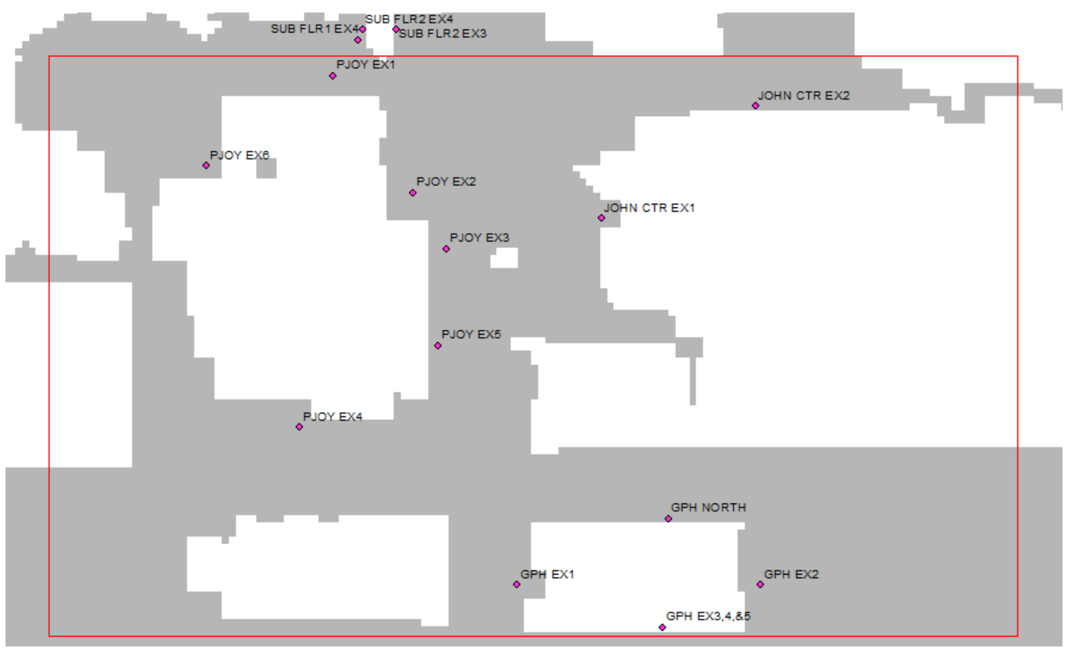


Figure 12.

Top: SUB and Mesa Vista Hall Bottom: Popejoy, Johnson Center, and George Pearl Hall

Figure 13.

Top: Castetter Hall

Bottom: West side of central campus

Table 2. 2 MPH Interior Retrieval Times and Exterior Ranges

Average Speed	2.93 ft/sec	Highlight=Approx.	2 MPH	2.933333333 ft/sec
	One way Int. Dist	One way Int. Time	Outdoor Range	
ADV EAST EX	213 Paces	181.7 Seconds	0 Feet	0 Meters
BLDG 116	25 Paces	21.3 Seconds	201 Feet	61 Meters
BLDG 149 EX	8 Paces	6.8 Seconds	244 Feet	74 Meters
CAST EX1	50 Paces	42.7 Seconds	139 Feet	42 Meters
CAST EX2	76 Paces	64.8 Seconds	74 Feet	22 Meters
CAST EX3	109 Paces	93.0 Seconds	0 Feet	0 Meters
CAST EX4	124 Paces	105.8 Seconds	0 Feet	0 Meters
CAST EX5	165 Paces	140.8 Seconds	0 Feet	0 Meters
CAST EX6	202 Paces	172.4 Seconds	0 Feet	0 Meters
CAST EX7	198 Paces	168.9 Seconds	0 Feet	0 Meters
CAST EX8	203 Paces	173.2 Seconds	0 Feet	0 Meters
ECE EX1	36 Paces	30.7 Seconds	174 Feet	53 Meters
ECE EX2	35 Paces	29.9 Seconds	176 Feet	54 Meters
ECE EX3	68 Paces	58.0 Seconds	94 Feet	29 Meters
ECE EX5	39 Paces	33.3 Seconds	166 Feet	51 Meters
ECON EX1	56.5 Paces	48.2 Seconds	122 Feet	37 Meters
ECON EX2	34 Paces	29.0 Seconds	179 Feet	54 Meters
ECON EX3	65 Paces	55.5 Seconds	101 Feet	31 Meters
ECON EX4	24 Paces	20.5 Seconds	204 Feet	62 Meters
GPH EX1	49 Paces	41.8 Seconds	141 Feet	43 Meters
GPH EX2	88 Paces	75.1 Seconds	44 Feet	13 Meters
GPH EX4	142 Paces	121.2 Seconds	0 Feet	0 Meters
GPH EX5	96 Paces	81.9 Seconds	24 Feet	7 Meters
GSM EX1	61 Paces	52.0 Seconds	111 Feet	34 Meters
GSM EX2	73 Paces	62.3 Seconds	81 Feet	25 Meters
JOHN CTR EX1	23 Paces	19.6 Seconds	206 Feet	63 Meters
McKINN EX1	28 Paces	23.9 Seconds	194 Feet	59 Meters
McKINN EX2	36 Paces	30.7 Seconds	174 Feet	53 Meters
McKINN EX4	40 Paces	34.1 Seconds	164 Feet	50 Meters
McKINN EX5	44 Paces	37.5 Seconds	154 Feet	47 Meters
MVH AREA3 COURT	178 Paces	151.9 Seconds	0 Feet	0 Meters

2 MPH Interior Retrieval Times and Exterior Ranges (cont.)

MVH ECOURT EX1	141 Paces	120.3 Seconds	0 Feet	0 Meters
MVH ECOURT EX2	64 Paces	54.6 Seconds	104 Feet	32 Meters
MVH WCOURT EX1	141 Paces	120.3 Seconds	0 Feet	0 Meters
MVH WCOURT EX2	104 Paces	88.7 Seconds	4 Feet	1 Meters
MVH WCOURT2 EX1	118 Paces	100.7 Seconds	0 Feet	0 Meters
MVH/ADV COURT EX1	118 Paces	100.7 Seconds	0 Feet	0 Meters
MVH/ADV COURT EX3	190 Paces	162.1 Seconds	0 Feet	0 Meters
MVH/ADV COURT EX4	188 Paces	160.4 Seconds	0 Feet	0 Meters
MVH/ADV COURT EX5	198 Paces	168.9 Seconds	0 Feet	0 Meters
MVH/CLINIC COURT EX1	53 Paces	45.2 Seconds	131 Feet	40 Meters
ORTEGA EX1	53 Paces	45.2 Seconds	131 Feet	40 Meters
ORTEGA EX2	113 Paces	96.4 Seconds	0 Feet	0 Meters
PJOY EX1 TO AED1	228 Paces	194.5 Seconds	0 Feet	0 Meters
PJOY EX2 TO AED1	122 Paces	104.1 Seconds	0 Feet	0 Meters
PJOY EX4 TO AED1	28 Paces	23.9 Seconds	194 Feet	59 Meters
PJOY EX3 TO AED2	21 Paces	17.9 Seconds	211 Feet	64 Meters
PJOY EX1 TO AED3	183 Paces	156.1 Seconds	0 Feet	0 Meters
PJOY EX2 TO AED3	81 Paces	69.1 Seconds	61 Feet	19 Meters
PJOY EX3 TO AED3	81 Paces	69.1 Seconds	61 Feet	19 Meters
SUB FLR1 EX1	80.5 Paces	68.7 Seconds	62 Feet	19 Meters
SUB FLR1 EX2	85 Paces	72.5 Seconds	51 Feet	16 Meters
SUB FLR1 EX3	50 Paces	42.7 Seconds	139 Feet	42 Meters
SUB FLR1 EX4	92.5 Paces	78.9 Seconds	32 Feet	10 Meters
SUB FLR2 EX1	53.5 Paces	45.6 Seconds	130 Feet	40 Meters
SUB FLR2 EX2	46 Paces	39.2 Seconds	149 Feet	45 Meters
SUB FLR2 EX3	92.5 Paces	78.9 Seconds	32 Feet	10 Meters
SUB FLR2 EX4	91 Paces	77.6 Seconds	36 Feet	11 Meters
SUB FLR2 EX5	67 Paces	57.2 Seconds	96 Feet	29 Meters
SUB FLR2 EX6	49 Paces	41.8 Seconds	141 Feet	43 Meters
SUB FLR2 EX7	73 Paces	62.3 Seconds	81 Feet	25 Meters
SUB FLR3 TO FLR2 EX1	80 Paces	68.3 Seconds	64 Feet	19 Meters
SUB FLR3 TO FLR2 EX3	130 Paces	110.9 Seconds	0 Feet	0 Meters
SUB FLR3 TO FLR2 EX4	131 Paces	111.8 Seconds	0 Feet	0 Meters

2 MPH Interior Retrieval Times and Exterior Ranges (cont.)

ZIM EX1	22 Paces	18.8 Seconds	209 Feet	64 Meters
ZIM EX2	52.5 Paces	44.8 Seconds	132 Feet	40 Meters

Figure 14. With a 2mph retrieval speed, exterior areas that are covered by just one AED are the most prevalent. These areas are denoted above by the more yellow color. Then, as coverage from two AED's overlap, the color shifts to orange. Finally, as three AED ranges overlap, the color changes to red.

Table 3. 3 MPH Interior Retrieval Times and Exterior Ranges

Average Speed	4.4 ft/sec	Highlight=Approx.	3 MPH	4.4 ft/sec
	One way Int. Dist	One way Int. Time	Outdoor Range	
ADV EAST EX	213 Paces	121.0 Seconds	0 Feet	0 Meters
BLDG 116	25 Paces	14.2 Seconds	334 Feet	102 Meters
BLDG 149 EX	8 Paces	4.5 Seconds	376 Feet	115 Meters
CAST EX1	50 Paces	28.4 Seconds	271 Feet	83 Meters
CAST EX2	76 Paces	43.2 Seconds	206 Feet	63 Meters
CAST EX3	109 Paces	61.9 Seconds	124 Feet	38 Meters
CAST EX4	124 Paces	70.5 Seconds	86 Feet	26 Meters
CAST EX5	165 Paces	93.8 Seconds	0 Feet	0 Meters
CAST EX6	202 Paces	114.8 Seconds	0 Feet	0 Meters
CAST EX7	198 Paces	112.5 Seconds	0 Feet	0 Meters
CAST EX8	203 Paces	115.3 Seconds	0 Feet	0 Meters
ECE EX1	36 Paces	20.5 Seconds	306 Feet	93 Meters
ECE EX2	35 Paces	19.9 Seconds	309 Feet	94 Meters
ECE EX3	68 Paces	38.6 Seconds	226 Feet	69 Meters
ECE EX5	39 Paces	22.2 Seconds	299 Feet	91 Meters
ECON EX1	56.5 Paces	32.1 Seconds	255 Feet	78 Meters
ECON EX2	34 Paces	19.3 Seconds	311 Feet	95 Meters
ECON EX3	65 Paces	36.9 Seconds	234 Feet	71 Meters
ECON EX4	24 Paces	13.6 Seconds	336 Feet	102 Meters
GPH EX1	49 Paces	27.8 Seconds	274 Feet	83 Meters
GPH EX2	88 Paces	50.0 Seconds	176 Feet	54 Meters
GPH EX4	142 Paces	80.7 Seconds	41 Feet	12 Meters
GPH EX5	96 Paces	54.5 Seconds	156 Feet	48 Meters
GSM EX1	61 Paces	34.7 Seconds	244 Feet	74 Meters
GSM EX2	73 Paces	41.5 Seconds	214 Feet	65 Meters
JOHN CTR EX1	23 Paces	13.1 Seconds	339 Feet	103 Meters
McKINN EX1	28 Paces	15.9 Seconds	326 Feet	99 Meters
McKINN EX2	36 Paces	20.5 Seconds	306 Feet	93 Meters
McKINN EX4	40 Paces	22.7 Seconds	296 Feet	90 Meters
McKINN EX5	44 Paces	25.0 Seconds	286 Feet	87 Meters
MVH AREA3 COURT	178 Paces	101.1 Seconds	0 Feet	0 Meters

3 MPH Interior Retrieval Times and Exterior Ranges (cont.)

MVH ECOURT EX1	141 Paces	80.1 Seconds	44 Feet	13 Meters
MVH ECOURT EX2	64 Paces	36.4 Seconds	236 Feet	72 Meters
MVH WCOURT EX1	141 Paces	80.1 Seconds	44 Feet	13 Meters
MVH WCOURT EX2	104 Paces	59.1 Seconds	136 Feet	41 Meters
MVH WCOURT2 EX1	118 Paces	67.0 Seconds	101 Feet	31 Meters
MVH/ADV COURT EX1	118 Paces	67.0 Seconds	101 Feet	31 Meters
MVH/ADV COURT EX3	190 Paces	108.0 Seconds	0 Feet	0 Meters
MVH/ADV COURT EX4	188 Paces	106.8 Seconds	0 Feet	0 Meters
MVH/ADV COURT EX5	198 Paces	112.5 Seconds	0 Feet	0 Meters
MVH/CLINIC COURT EX1	53 Paces	30.1 Seconds	264 Feet	80 Meters
ORTEGA EX1	53 Paces	30.1 Seconds	264 Feet	80 Meters
ORTEGA EX2	113 Paces	64.2 Seconds	114 Feet	35 Meters
PJOY EX1 TO AED1	228 Paces	129.5 Seconds	0 Feet	0 Meters
PJOY EX2 TO AED1	122 Paces	69.3 Seconds	91 Feet	28 Meters
PJOY EX4 TO AED1	28 Paces	15.9 Seconds	326 Feet	99 Meters
PJOY EX3 TO AED2	21 Paces	11.9 Seconds	344 Feet	105 Meters
PJOY EX1 TO AED3	183 Paces	104.0 Seconds	0 Feet	0 Meters
PJOY EX2 TO AED3	81 Paces	46.0 Seconds	194 Feet	59 Meters
PJOY EX3 TO AED3	81 Paces	46.0 Seconds	194 Feet	59 Meters
SUB FLR1 EX1	80.5 Paces	45.7 Seconds	195 Feet	59 Meters
SUB FLR1 EX2	85 Paces	48.3 Seconds	184 Feet	56 Meters
SUB FLR1 EX3	50 Paces	28.4 Seconds	271 Feet	83 Meters
SUB FLR1 EX4	92.5 Paces	52.6 Seconds	165 Feet	50 Meters
SUB FLR2 EX1	53.5 Paces	30.4 Seconds	262 Feet	80 Meters
SUB FLR2 EX2	46 Paces	26.1 Seconds	281 Feet	86 Meters
SUB FLR2 EX3	92.5 Paces	52.6 Seconds	165 Feet	50 Meters
SUB FLR2 EX4	91 Paces	51.7 Seconds	169 Feet	51 Meters
SUB FLR2 EX5	67 Paces	38.1 Seconds	229 Feet	70 Meters
SUB FLR2 EX6	49 Paces	27.8 Seconds	274 Feet	83 Meters
SUB FLR2 EX7	73 Paces	41.5 Seconds	214 Feet	65 Meters
SUB FLR3 TO FLR2 EX1	80 Paces	45.5 Seconds	196 Feet	60 Meters
SUB FLR3 TO FLR2 EX3	130 Paces	73.9 Seconds	71 Feet	22 Meters
SUB FLR3 TO FLR2 EX4	131 Paces	74.4 Seconds	69 Feet	21 Meters

3 MPH Interior Retrieval Times and Exterior Ranges (cont.)

ZIM EX1	22 Paces	12.5 Seconds	341 Feet	104 Meters
ZIM EX2	52.5 Paces	29.8 Seconds	265 Feet	81 Meters

Figure 15. With a 3mph retrieval speed, up to five AED's can overlap. Following the same color scheme as before, yellow indicates coverage by one AED, whereas the red shows areas with five overlapping AED ranges. The intermediate steps are shown in the color scale in the upper right.

Table 4. 5 MPH Interior Retrieval Times and Exterior Ranges

Average Speed	7.33 ft/sec	Highlight=Approx.	5 MPH	7.333333333 ft/sec
	One way Int. Dist	One way Int. Time	Outdoor Range	
ADV EAST EX	213 Paces	72.6 Seconds	127 Feet	39 Meters
BLDG 116	25 Paces	8.5 Seconds	597 Feet	182 Meters
BLDG 149 EX	8 Paces	2.7 Seconds	640 Feet	195 Meters
CAST EX1	50 Paces	17.1 Seconds	535 Feet	163 Meters
CAST EX2	76 Paces	25.9 Seconds	470 Feet	143 Meters
CAST EX3	109 Paces	37.2 Seconds	387 Feet	118 Meters
CAST EX4	124 Paces	42.3 Seconds	350 Feet	107 Meters
CAST EX5	165 Paces	56.3 Seconds	247 Feet	75 Meters
CAST EX6	202 Paces	68.9 Seconds	155 Feet	47 Meters
CAST EX7	198 Paces	67.5 Seconds	165 Feet	50 Meters
CAST EX8	203 Paces	69.2 Seconds	152 Feet	46 Meters
ECE EX1	36 Paces	12.3 Seconds	570 Feet	174 Meters
ECE EX2	35 Paces	11.9 Seconds	572 Feet	174 Meters
ECE EX3	68 Paces	23.2 Seconds	490 Feet	149 Meters
ECE EX5	39 Paces	13.3 Seconds	562 Feet	171 Meters
ECON EX1	56.5 Paces	19.3 Seconds	518 Feet	158 Meters
ECON EX2	34 Paces	11.6 Seconds	575 Feet	175 Meters
ECON EX3	65 Paces	22.2 Seconds	497 Feet	152 Meters
ECON EX4	24 Paces	8.2 Seconds	600 Feet	183 Meters
GPH EX1	49 Paces	16.7 Seconds	537 Feet	164 Meters
GPH EX2	88 Paces	30.0 Seconds	440 Feet	134 Meters
GPH EX4	142 Paces	48.4 Seconds	305 Feet	93 Meters
GPH EX5	96 Paces	32.7 Seconds	420 Feet	128 Meters
GSM EX1	61 Paces	20.8 Seconds	507 Feet	155 Meters
GSM EX2	73 Paces	24.9 Seconds	477 Feet	145 Meters
JOHN CTR EX1	23 Paces	7.8 Seconds	602 Feet	184 Meters
McKINN EX1	28 Paces	9.5 Seconds	590 Feet	180 Meters
McKINN EX2	36 Paces	12.3 Seconds	570 Feet	174 Meters
McKINN EX4	40 Paces	13.6 Seconds	560 Feet	171 Meters
McKINN EX5	44 Paces	15.0 Seconds	550 Feet	168 Meters
MVH AREA3 COURT	178 Paces	60.7 Seconds	215 Feet	65 Meters

5 MPH Interior Retrieval Times and Exterior Ranges (cont.)

MVH ECOURT EX1	141 Paces	48.1 Seconds	307 Feet	94 Meters
MVH ECOURT EX2	64 Paces	21.8 Seconds	500 Feet	152 Meters
MVH WCOURT EX1	141 Paces	48.1 Seconds	307 Feet	94 Meters
MVH WCOURT EX2	104 Paces	35.5 Seconds	400 Feet	122 Meters
MVH WCOURT2 EX1	118 Paces	40.2 Seconds	365 Feet	111 Meters
MVH/ADV COURT EX1	118 Paces	40.2 Seconds	365 Feet	111 Meters
MVH/ADV COURT EX3	190 Paces	64.8 Seconds	185 Feet	56 Meters
MVH/ADV COURT EX4	188 Paces	64.1 Seconds	190 Feet	58 Meters
MVH/ADV COURT EX5	198 Paces	67.5 Seconds	165 Feet	50 Meters
MVH/CLINIC COURT EX1	53 Paces	18.1 Seconds	527 Feet	161 Meters
ORTEGA EX1	53 Paces	18.1 Seconds	527 Feet	161 Meters
ORTEGA EX2	113 Paces	38.5 Seconds	377 Feet	115 Meters
PJOY EX1 TO AED1	228 Paces	77.8 Seconds	90 Feet	27 Meters
PJOY EX2 TO AED1	122 Paces	41.6 Seconds	355 Feet	108 Meters
PJOY EX4 TO AED1	28 Paces	9.5 Seconds	590 Feet	180 Meters
PJOY EX3 TO AED2	21 Paces	7.2 Seconds	607 Feet	185 Meters
PJOY EX1 TO AED3	183 Paces	62.4 Seconds	202 Feet	62 Meters
PJOY EX2 TO AED3	81 Paces	27.6 Seconds	457 Feet	139 Meters
PJOY EX3 TO AED3	81 Paces	27.6 Seconds	457 Feet	139 Meters
SUB FLR1 EX1	80.5 Paces	27.5 Seconds	458 Feet	140 Meters
SUB FLR1 EX2	85 Paces	29.0 Seconds	447 Feet	136 Meters
SUB FLR1 EX3	50 Paces	17.1 Seconds	535 Feet	163 Meters
SUB FLR1 EX4	92.5 Paces	31.5 Seconds	428 Feet	131 Meters
SUB FLR2 EX1	53.5 Paces	18.2 Seconds	526 Feet	160 Meters
SUB FLR2 EX2	46 Paces	15.7 Seconds	545 Feet	166 Meters
SUB FLR2 EX3	92.5 Paces	31.5 Seconds	428 Feet	131 Meters
SUB FLR2 EX4	91 Paces	31.0 Seconds	432 Feet	132 Meters
SUB FLR2 EX5	67 Paces	22.9 Seconds	492 Feet	150 Meters
SUB FLR2 EX6	49 Paces	16.7 Seconds	537 Feet	164 Meters
SUB FLR2 EX7	73 Paces	24.9 Seconds	477 Feet	145 Meters
SUB FLR3 TO FLR2 EX1	80 Paces	27.3 Seconds	460 Feet	140 Meters
SUB FLR3 TO FLR2 EX3	130 Paces	44.3 Seconds	335 Feet	102 Meters
SUB FLR3 TO FLR2 EX4	131 Paces	44.7 Seconds	332 Feet	101 Meters

5 MPH Interior Retrieval Times and Exterior Ranges (cont.)

ZIM EX1	22 Paces	7.5 Seconds	605 Feet	184 Meters
ZIM EX2	52.5 Paces	17.9 Seconds	528 Feet	161 Meters

Figure 16. The pattern continues with 5mph. Individual ranges increase with the faster speed, and more overlapping occurs with possible coverage of up to eight AED's. Note the growing areas of red and those that are still black.

Table 5. 7 MPH Interior Retrieval Times and Exterior Ranges

Average Speed	10.27 ft/sec	Highlight=Approx.	7 MPH	10.26666667 ft/sec
	One way Int. Dist	One way Int. Time	Outdoor Range	
ADV EAST EX	213 Paces	51.9 Seconds	392 Feet	119 Meters
BLDG 116	25 Paces	6.1 Seconds	862 Feet	263 Meters
BLDG 149 EX	8 Paces	1.9 Seconds	904 Feet	276 Meters
CAST EX1	50 Paces	12.2 Seconds	799 Feet	244 Meters
CAST EX2	76 Paces	18.5 Seconds	734 Feet	224 Meters
CAST EX3	109 Paces	26.5 Seconds	652 Feet	199 Meters
CAST EX4	124 Paces	30.2 Seconds	614 Feet	187 Meters
CAST EX5	165 Paces	40.2 Seconds	512 Feet	156 Meters
CAST EX6	202 Paces	49.2 Seconds	419 Feet	128 Meters
CAST EX7	198 Paces	48.2 Seconds	429 Feet	131 Meters
CAST EX8	203 Paces	49.4 Seconds	417 Feet	127 Meters
ECE EX1	36 Paces	8.8 Seconds	834 Feet	254 Meters
ECE EX2	35 Paces	8.5 Seconds	837 Feet	255 Meters
ECE EX3	68 Paces	16.6 Seconds	754 Feet	230 Meters
ECE EX5	39 Paces	9.5 Seconds	827 Feet	252 Meters
ECON EX1	56.5 Paces	13.8 Seconds	783 Feet	239 Meters
ECON EX2	34 Paces	8.3 Seconds	839 Feet	256 Meters
ECON EX3	65 Paces	15.8 Seconds	762 Feet	232 Meters
ECON EX4	24 Paces	5.8 Seconds	864 Feet	263 Meters
GPH EX1	49 Paces	11.9 Seconds	802 Feet	244 Meters
GPH EX2	88 Paces	21.4 Seconds	704 Feet	215 Meters
GPH EX4	142 Paces	34.6 Seconds	569 Feet	174 Meters
GPH EX5	96 Paces	23.4 Seconds	684 Feet	209 Meters
GSM EX1	61 Paces	14.8 Seconds	772 Feet	235 Meters
GSM EX2	73 Paces	17.8 Seconds	742 Feet	226 Meters
JOHN CTR EX1	23 Paces	5.6 Seconds	867 Feet	264 Meters
McKINN EX1	28 Paces	6.8 Seconds	854 Feet	260 Meters
McKINN EX2	36 Paces	8.8 Seconds	834 Feet	254 Meters
McKINN EX4	40 Paces	9.7 Seconds	824 Feet	251 Meters
McKINN EX5	44 Paces	10.7 Seconds	814 Feet	248 Meters
MVH AREA3 COURT	178 Paces	43.3 Seconds	479 Feet	146 Meters

7 MPH Interior Retrieval Times and Exterior Ranges (cont.)

MVH ECOURT EX1	141 Paces	34.3 Seconds	572 Feet	174 Meters
MVH ECOURT EX2	64 Paces	15.6 Seconds	764 Feet	233 Meters
MVH WCOURT EX1	141 Paces	34.3 Seconds	572 Feet	174 Meters
MVH WCOURT EX2	104 Paces	25.3 Seconds	664 Feet	202 Meters
MVH WCOURT2 EX1	118 Paces	28.7 Seconds	629 Feet	192 Meters
MVH/ADV COURT EX1	118 Paces	28.7 Seconds	629 Feet	192 Meters
MVH/ADV COURT EX3	190 Paces	46.3 Seconds	449 Feet	137 Meters
MVH/ADV COURT EX4	188 Paces	45.8 Seconds	454 Feet	138 Meters
MVH/ADV COURT EX5	198 Paces	48.2 Seconds	429 Feet	131 Meters
MVH/CLINIC COURT EX1	53 Paces	12.9 Seconds	792 Feet	241 Meters
ORTEGA EX1	53 Paces	12.9 Seconds	792 Feet	241 Meters
ORTEGA EX2	113 Paces	27.5 Seconds	642 Feet	196 Meters
PJOY EX1 TO AED1	228 Paces	55.5 Seconds	354 Feet	108 Meters
PJOY EX2 TO AED1	122 Paces	29.7 Seconds	619 Feet	189 Meters
PJOY EX4 TO AED1	28 Paces	6.8 Seconds	854 Feet	260 Meters
PJOY EX3 TO AED2	21 Paces	5.1 Seconds	872 Feet	266 Meters
PJOY EX1 TO AED3	183 Paces	44.5 Seconds	467 Feet	142 Meters
PJOY EX2 TO AED3	81 Paces	19.7 Seconds	722 Feet	220 Meters
PJOY EX3 TO AED3	81 Paces	19.7 Seconds	722 Feet	220 Meters
SUB FLR1 EX1	80.5 Paces	19.6 Seconds	723 Feet	220 Meters
SUB FLR1 EX2	85 Paces	20.7 Seconds	712 Feet	217 Meters
SUB FLR1 EX3	50 Paces	12.2 Seconds	799 Feet	244 Meters
SUB FLR1 EX4	92.5 Paces	22.5 Seconds	693 Feet	211 Meters
SUB FLR2 EX1	53.5 Paces	13.0 Seconds	791 Feet	241 Meters
SUB FLR2 EX2	46 Paces	11.2 Seconds	809 Feet	247 Meters
SUB FLR2 EX3	92.5 Paces	22.5 Seconds	693 Feet	211 Meters
SUB FLR2 EX4	91 Paces	22.2 Seconds	697 Feet	212 Meters
SUB FLR2 EX5	67 Paces	16.3 Seconds	757 Feet	231 Meters
SUB FLR2 EX6	49 Paces	11.9 Seconds	802 Feet	244 Meters
SUB FLR2 EX7	73 Paces	17.8 Seconds	742 Feet	226 Meters
SUB FLR3 TO FLR2 EX1	80 Paces	19.5 Seconds	724 Feet	221 Meters
SUB FLR3 TO FLR2 EX3	130 Paces	31.6 Seconds	599 Feet	183 Meters
SUB FLR3 TO FLR2 EX4	131 Paces	31.9 Seconds	597 Feet	182 Meters

7 MPH Interior Retrieval Times and Exterior Ranges (cont.)

ZIM EX1	22 Paces	5.4 Seconds	869 Feet	265 Meters
ZIM EX2	52.5 Paces	12.8 Seconds	793 Feet	242 Meters

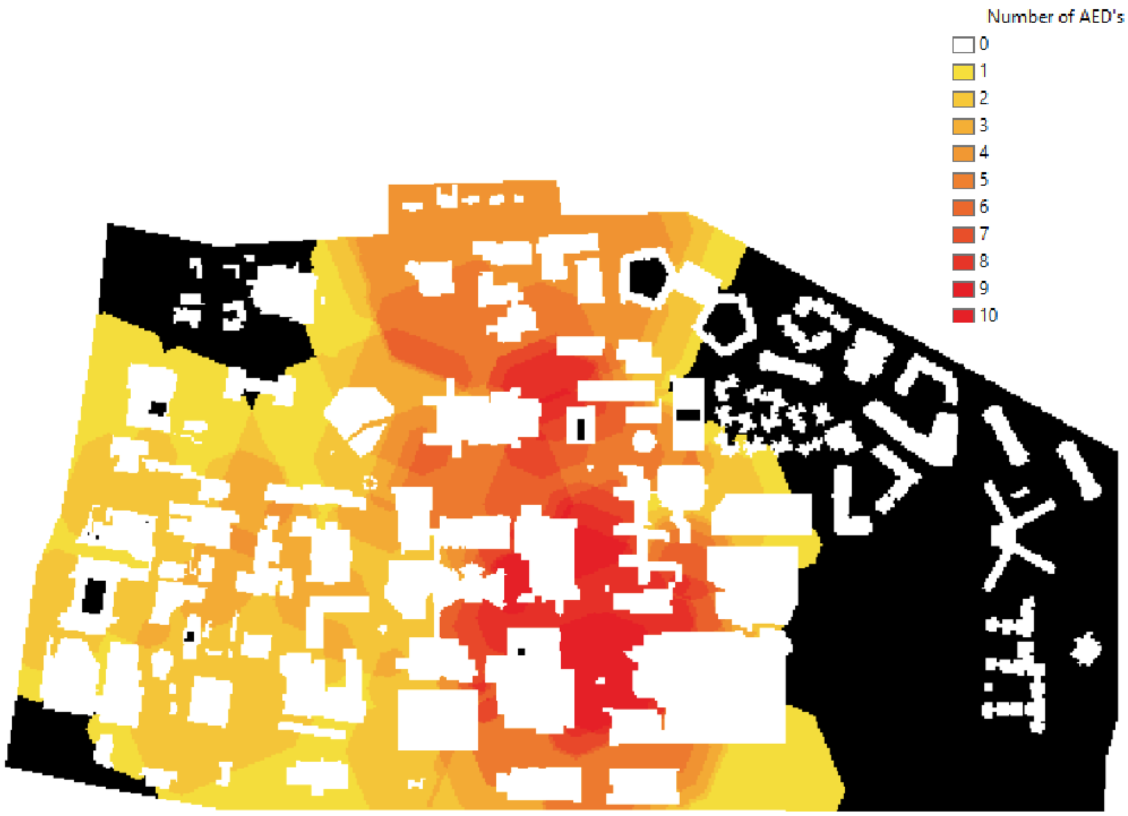


Figure 17. At 7mph, and with up to 10 AED ranges overlapping, it is difficult to discern the individual gradients with the naked eye.

Table 6. 10 MPH Interior Retrieval Times and Exterior Ranges

Average Speed	14.67 ft/sec	Highlight=Approx.	10 MPH	14.66666667 ft/sec
	One way Int. Dist	One way Int. Time	Outdoor Range	
ADV EAST EX	213 Paces	36.3 Seconds	788	240 Meters
BLDG 116	25 Paces	4.3 Seconds	1258 Feet	383 Meters
BLDG 149 EX	8 Paces	1.4 Seconds	1300 Feet	396 Meters
CAST EX1	50 Paces	8.5 Seconds	1195 Feet	364 Meters
CAST EX2	76 Paces	13.0 Seconds	1130 Feet	344 Meters
CAST EX3	109 Paces	18.6 Seconds	1048 Feet	319 Meters
CAST EX4	124 Paces	21.1 Seconds	1010 Feet	308 Meters
CAST EX5	165 Paces	28.1 Seconds	908 Feet	277 Meters
CAST EX6	202 Paces	34.4 Seconds	815 Feet	248 Meters
CAST EX7	198 Paces	33.7 Seconds	825 Feet	252 Meters
CAST EX8	203 Paces	34.6 Seconds	813 Feet	248 Meters
ECE EX1	36 Paces	6.1 Seconds	1230 Feet	375 Meters
ECE EX2	35 Paces	6.0 Seconds	1233 Feet	376 Meters
ECE EX3	68 Paces	11.6 Seconds	1150 Feet	351 Meters
ECE EX5	39 Paces	6.6 Seconds	1223 Feet	373 Meters
ECON EX1	56.5 Paces	9.6 Seconds	1179 Feet	359 Meters
ECON EX2	34 Paces	5.8 Seconds	1235 Feet	377 Meters
ECON EX3	65 Paces	11.1 Seconds	1158 Feet	353 Meters
ECON EX4	24 Paces	4.1 Seconds	1260 Feet	384 Meters
GPH EX1	49 Paces	8.4 Seconds	1198 Feet	365 Meters
GPH EX2	88 Paces	15.0 Seconds	1100 Feet	335 Meters
GPH EX4	142 Paces	24.2 Seconds	965 Feet	294 Meters
GPH EX5	96 Paces	16.4 Seconds	1080 Feet	329 Meters
GSM EX1	61 Paces	10.4 Seconds	1168 Feet	356 Meters
GSM EX2	73 Paces	12.4 Seconds	1138 Feet	347 Meters
JOHN CTR EX1	23 Paces	3.9 Seconds	1263 Feet	385 Meters
McKINN EX1	28 Paces	4.8 Seconds	1250 Feet	381 Meters
McKINN EX2	36 Paces	6.1 Seconds	1230 Feet	375 Meters
McKINN EX4	40 Paces	6.8 Seconds	1220 Feet	372 Meters
McKINN EX5	44 Paces	7.5 Seconds	1210 Feet	369 Meters
MVH AREA3 COURT	178 Paces	30.3 Seconds	875 Feet	267 Meters

10 MPH Interior Retrieval Times and Exterior Ranges (cont.)

MVH ECOURT EX1	141 Paces	24.0 Seconds	968 Feet	295 Meters
MVH ECOURT EX2	64 Paces	10.9 Seconds	1160 Feet	354 Meters
MVH WCOURT EX1	141 Paces	24.0 Seconds	968 Feet	295 Meters
MVH WCOURT EX2	104 Paces	17.7 Seconds	1060 Feet	323 Meters
MVH WCOURT2 EX1	118 Paces	20.1 Seconds	1025 Feet	312 Meters
MVH/ADV COURT EX1	118 Paces	20.1 Seconds	1025 Feet	312 Meters
MVH/ADV COURT EX3	190 Paces	32.4 Seconds	845 Feet	258 Meters
MVH/ADV COURT EX4	188 Paces	32.0 Seconds	850 Feet	259 Meters
MVH/ADV COURT EX5	198 Paces	33.7 Seconds	825 Feet	252 Meters
MVH/CLINIC COURT EX1	53 Paces	9.0 Seconds	1188 Feet	362 Meters
ORTEGA EX1	53 Paces	9.0 Seconds	1188 Feet	362 Meters
ORTEGA EX2	113 Paces	19.3 Seconds	1038 Feet	316 Meters
PJOY EX1 TO AED1	228 Paces	38.9 Seconds	750 Feet	229 Meters
PJOY EX2 TO AED1	122 Paces	20.8 Seconds	1015 Feet	309 Meters
PJOY EX4 TO AED1	28 Paces	4.8 Seconds	1250 Feet	381 Meters
PJOY EX3 TO AED2	21 Paces	3.6 Seconds	1268 Feet	386 Meters
PJOY EX1 TO AED3	183 Paces	31.2 Seconds	863 Feet	263 Meters
PJOY EX2 TO AED3	81 Paces	13.8 Seconds	1118 Feet	341 Meters
PJOY EX3 TO AED3	81 Paces	13.8 Seconds	1118 Feet	341 Meters
SUB FLR1 EX1	80.5 Paces	13.7 Seconds	1119 Feet	341 Meters
SUB FLR1 EX2	85 Paces	14.5 Seconds	1108 Feet	338 Meters
SUB FLR1 EX3	50 Paces	8.5 Seconds	1195 Feet	364 Meters
SUB FLR1 EX4	92.5 Paces	15.8 Seconds	1089 Feet	332 Meters
SUB FLR2 EX1	53.5 Paces	9.1 Seconds	1187 Feet	362 Meters
SUB FLR2 EX2	46 Paces	7.8 Seconds	1205 Feet	367 Meters
SUB FLR2 EX3	92.5 Paces	15.8 Seconds	1089 Feet	332 Meters
SUB FLR2 EX4	91 Paces	15.5 Seconds	1093 Feet	333 Meters
SUB FLR2 EX5	67 Paces	11.4 Seconds	1153 Feet	351 Meters
SUB FLR2 EX6	49 Paces	8.4 Seconds	1198 Feet	365 Meters
SUB FLR2 EX7	73 Paces	12.4 Seconds	1138 Feet	347 Meters
SUB FLR3 TO FLR2 EX1	80 Paces	13.6 Seconds	1120 Feet	341 Meters
SUB FLR3 TO FLR2 EX3	130 Paces	22.2 Seconds	995 Feet	303 Meters
SUB FLR3 TO FLR2 EX4	131 Paces	22.3 Seconds	993 Feet	303 Meters

10 MPH Interior Retrieval Times and Exterior Ranges (cont.)

ZIM EX1	22 Paces	3.7 Seconds	1265 Feet	386 Meters
ZIM EX2	52.5 Paces	8.9 Seconds	1189 Feet	362 Meters

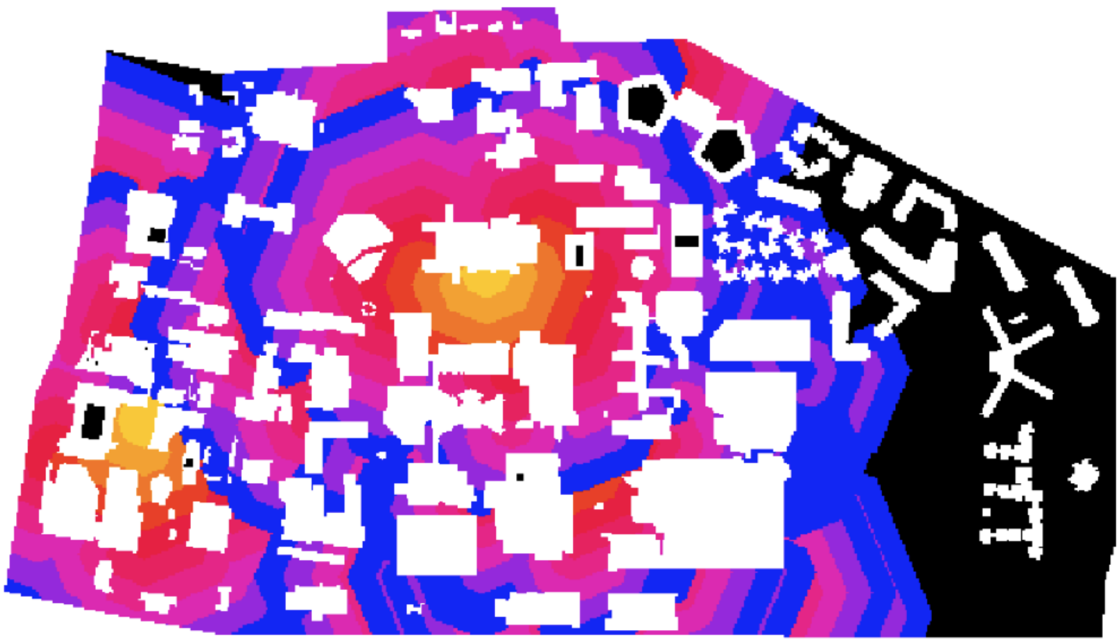


Figure 18. As stated earlier, the full analysis was not done with a retrieval speed of 10mph, as this speed was felt to be unrealistic. The overall extent of coverage at this speed is shown here, not the degree of overlapping coverage as in Figures 14-17. Notice that even at this extreme speed there is still an area of eastern campus that is not covered by a single AED.

The figures on the previous pages show the extent of AED coverage on central campus for the various speed scenarios. Below is a table of the amount of pixels (again, representing 10’x10’ areas of the exterior campus) that are covered by AED’s.

Table 7.

Campus AED Coverage 10’x10’ Pixels		Pixels Covered 7MPH	5MPH	3MPH	2MPH
Number of AED’s					
	1	9875	15432	12175	6760
	2	12453	7838	3072	1311
	3	5162	2276	2981	296
	4	5589	4933	628	
	5	5544	3441	31	
	6	2343	347		
	7	1766	531		
	8	2451	986		
	9	1984			
	10	34			
Study Area covered		47201	35784	18887	8367
Total Area Friction Surface		78143			
Exterior Area covered		60.40%	45.79%	24.17%	10.71%

At a 2mph walking speed, 8,367 pixels out of the 78,143 that make up the study area, or about 11%, are covered by at least one AED. At a faster 3mph walking speed, perhaps qualifying as the AHA’s “brisk walk,” 18,887 pixels, about 24% of the study area, are within reach of an AED.

A greater sense of urgency seems reasonable, and at 5mph 35,784 pixels representing close to 46% of the study area have access to an AED. A 7mph retrieval speed yields about 60% coverage. The pixel coverage at 10mph was not calculated, and the analysis was not taken past the initial Cost Distance step as it was felt that this speed was unrealistic. A visual sense of the coverage this speed could produce can be seen in Figure 18.

VII. Discussion

The University of New Mexico has buildings that are very well covered by AED's. There are also outdoor areas, most notably the area bound by the SUB, Mesa Vista Hall, the Center for the Arts, and the Johnson Center, that have access to multiple AED's. However, even under a realistic scenario of a 5mph retrieval speed, less than half of the outdoor portion of the study area is covered. If the focus were confined to those AED's accessible by the "brisk walk" recommended by the AHA, less than a quarter of the study area would be served by an AED.

This model makes a number of assumptions. One of which is that everything will go well, and at its most efficient. Instant recognition of the OHCA incident will be made by witnesses, who will know just what to do and where to go, and will take the most direct and fastest route to get there. The buildings on campus will all be open, and pedestrian traffic and barriers will not be an issue. People will know what an AED is when you ask for it. It was necessary to simplify reality in order to make the model, and these were the assumptions made to do so. The result is that the effective ranges obtained are the best case scenario for the varying retrieval speeds. Not a second is to be lost in hesitation or wasted effort.

That is not to say that the results of this model are necessarily an overestimation of campus AED coverage. They may well be, but there are other potential sources of error. Obviously pacing is not the most exacting measurement tool. Nor are GPS coordinates perfectly accurate. There are also a number of steps during the GIS analysis where errors could have been made.

Another conceivable source of error is the possible existence of AED's outside the study area whose effective ranges might reach into campus. Especially on the other side of University Blvd and Central Ave are a number of businesses and institutions such as churches that may very well have AED's. However, for an OHCA on campus the retrieval of such an AED is likely to be delayed by crossing these busy roads that represent very real barriers to foot travel. It is easy to imagine spending the entire minute and a half available looking for a break in traffic. Most boundary roads of the study area produce significant changes in travel speed, or they border areas unlikely to have AED’s.

Even with potential error, the model does reveal a number of patterns. The eastern side of campus is not covered at all by AED’s, or at least by PAD’s (more on this below) even at the extreme best case scenario of a 10mph retrieval speed. This is furthermore where the student dormitories are located, living areas that are occupied much of the time. It is true that the student population living on campus is typically younger and less at risk of OHCA, but it can not definitively be said that it will not happen. There is also the possibility of a subset, perhaps transient, population that is more at risk: visiting parents and friends, campus employees, professors and older students walking through this area of campus, etc. One need not be considered elderly to be victim of a heart attack (McKay).

It was said earlier that the eastern portion of central campus is not covered by PAD’s. It may very well be covered by AED’s, but these would be mobile in nature. One thing not discussed in this paper is the role of the fire department and/or campus police in responding to OHCA’s. They would have defibrillators with them, and likely would be among the first responders to an OHCA on campus, however, the focus of this paper is the window of time between the onset of an OHCA and the arrival of EMS. So while eastern campus may be served by these AED’s, the general public would be limited to CPR until help arrived.

While there are a number of buildings on campus that could be equipped with AED’s, it may also be possible to install AED’s outdoors in some kind of kiosk to cover the otherwise hard to reach areas such as the parking lots in the northwest and southeast corners of central campus. It is not known how much exposure to temperature extremes might effect these machines, but some type of insulated box seems like it would be a reasonable option. The image to the right is an example of a simple outdoor kiosk for an AED in Florence, Italy, a city that can experience fairly high temperatures. Note the separated roof structure to minimize solar heating. Such a setup would have to be monitored and maintained, but such is the case with any preventative device.

PAD storage in general is another consideration that actually bears on the model created in this paper. An AED is not very big, and there are multiple ways to store them, some examples of which can be seen on campus. The best way by far is in some sort of built-in box in a very visible place. Examples of this can be seen on all three floors of the SUB (picture on the left), or in the John and June Perovich Business Center (image on the right below). Of the two, the Business Center has the added advantage of the “AED” sign visible from down the hallway.

Notice the proximity and similarity to the fire safety features in the above example. AED’s should be highly visible, easily accessible, and easy to maintain. One of the reasons that this type of installation could be considered superior than other methods of storing AED’s is the fact that the AED is not going to move around. There is no temptation for anyone to move it, as it is not in anyone’s way, an alarm will sound if the door is opened, and the actual box is installed in such a permanent way that it would take serious effort to remove it. Essentially, the AED can be relied upon to be in a known location, which is a premise that this paper is based on.

Contrast this with some other ways that AED's are stored on campus. As can be seen in the photos, AED's often have a carrying strap and sometimes are contained in a small duffle bag. They are designed to be easy to carry to the site of an emergency, which is good, but in some cases they are stored in an office on a desk or a cabinet. This is not necessary a bad thing, as long as that place is dedicated to that AED. The problem is that because the AED is by design easily moveable, and hopefully infrequently used, there may arise a temptation to get it out of the way or to move it temporarily. Then the AED is no longer where it is supposed to be, which can be a real problem in an emergency situation. This is not to criticize anyone, and having an AED at all should be applauded, but this storage method is not as good as the dedicated box or kiosk described earlier.

The least optimal method of AED storage on campus from a PAD perspective is in a drawer. This is a simple problem of visibility. Even if the drawer is labeled, unless there is an office worker present who knows that the AED is there and knows what it is (not a given, unfortunately), the chance that a bystander would find it in the narrow window of time at their disposal is small.

Simply because there is room for improvement for AED placement on the UNM central campus, it should not follow that the situation is hopeless. On the contrary, there are a number of things, especially in terms of education, that could greatly improve the PAD program at UNM. There are also a number of things already in place that are very positive. Many buildings on campus are well covered by AED's, especially their interior spaces. There is also an exterior corridor through central campus that is well covered. If there were such a thing as a good place to experience an OHCA outdoors at UNM, it would be to the east and southeast of the SUB. This would be true even without counting the AED's in Popejoy Hall. The AED's in the Center of the Arts do contribute to this area coverage, but the reality is that these AED's are only accessible during performances, when the interior doors to Popejoy Hall are unlocked. However, one would have to know that these AED's were there for them to be of any use. This brings up an important point, which is awareness of AED's at UNM.

While collecting the data for this project, even with the spreadsheet of AED locations, it was sometimes difficult to find these devices in the real world. At times it was necessary to ask in an office where the unit was actually located. This is the visibility problem mentioned earlier, and while this illustrates that the AED location itself lacked adequate notice of its whereabouts, what was perhaps more disconcerting were the frequent blank faces that questions about AED's prompted. "What is an AED?" was a frequent question, and "Is that what that thing is?" was another that was heard. While this is anecdotal, it does suggest that first aid and AED education on campus is not what it could be. This is especially the case in the entrance office of the Johnson Center (the gymnasium and fitness complex on campus), an area at high risk of witnessing OHCA's.

In other words, in addition to a visibility problem in some cases, there appears to also be a lack of knowledge about the seriousness and prevalence of heart attacks, as well as of responsive measures. Even when everything goes well, survival rates of OHCA are still not great. The idea behind PAD programs as well as this paper is to improve every aspect of the response that we have control over. Hopefully this project will shed some light on the present situation of AED placement on campus, and may perhaps inspire similar investigations of other sites, with the aim of more effectively and efficiently arranging AED's in public places. However, even the best AED array in the world will amount to little if only a small portion of people on campus know what an AED even is. Education is definitely something that we have control over, so why not make UNM a leader of heart attack awareness and first response preparedness?

VIII. Conclusion

The model shows exterior study area coverage of roughly 11% at 2mph, 24% at 3mph, 46% at 5mph, and 60% at 7mph. Using 3mph as an approximation of the recommendations by the AHA, less than a quarter of the outdoor portion of the UNM main campus is covered. With the perhaps more realistic scenario of 5mph, less than half of the exterior campus receives coverage. The eastern portion of campus is not covered by PAD's at any speed studied.

With these results, it is felt that more deliberation is needed when it comes to AED placement, as well as in the storage method chosen. The reason for the latter is the inherent fact that an AED that can be repositioned easily and without notice when not in use is less reliable than one that has a designated and built in storage location. It also may be advantageous to develop and install outdoor AED kiosks to serve hard to reach areas of campus.

Perhaps most importantly and urgently, education of the topics of cardiac arrest and defibrillation needs to be expanded on the UNM campus. Few people would need an explanation of a fire extinguisher, and it seems like the same should be true for an AED. Whether the problem resides in the name or the concept is not certain, but both could be relatively easily dealt with an increase in First Aid and AED certification by the UNM student body.

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