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Khalaf Alsalem

Abdullah Al-Eissa

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*Completed Research Paper*

**Khalaf Alsalem**
Claremont Graduate University
150 E 10th St, Claremont, CA 91711
khalaf.alsalem@cgu.edu

**Abdullah Al-Eissa**
Claremont Graduate University
150 E 10th St, Claremont, CA 91711
abdullah.aleissa@cgu.edu

## Abstract

*Blue light emergency phone towers are essential for universities campuses. They have been providing security on campuses for at least three decades. These towers prevent, to some degree, crimes and also help in emergencies by providing direct access to police stations/campus security. Therefore, it is important to locate these towers where appropriate and to also know how many of these towers are sufficient for a certain area based on area size. The main tools used in this project are Euclidean Distance, Average Nearest Neighbor, Raster Calculator, Raster to Polygon, Intersect tool, and Viewshed Analysis. This research is intended for use by any college or university authorities charged with campus safety. It is expected to help them identify the locations that need more, or less, blue light emergency towers. This will assure the safety of their students and help them be confident that all areas are covered with these towers.*

**Keywords:** Blue light phones, blue light towers, emergency phones, campus safety.

## Introduction

Blue light emergency phone towers are essential for universities campuses. Blue light phones have been providing security on campuses for at least three decades. These towers prevent, to some degree, crimes and also help in emergencies by providing direct access to police stations/campus security. They are highly visible and easy to access and this had made them effective. The presences of such phones provide peace of mind for parents, students, employees and visitors on campus.

However, it is important to locate these towers where appropriate and to also know how many of these towers are sufficient for a certain area based on area size. This is part of the facility location problem and geographical insight plays an important role in this (Murray and Tong 2007). Knowing this would increase the safety of students, staffs, workers and neighbors around. In addition, it would help identify redundant towers that are not needed and reduce unwanted costs. Location and allocation is important and this can be enhanced by GIS (Church and Murray 2008).

Many organizations have written about blue light emergency phone towers. They highlighted the importance of these towers and also what make them so unique from cell phones. For example, in the case of using these towers, the police / security campus center will automatically know where the call is coming from and quickly send an officer to the exact location ("Blue Light Emergency Phones" 2012). This cannot be easily done in the case of calling from a mobile phone. However, installing these towers is costly while maintaining them is an ongoing expense (DI Editorial Board 2012). This study aims to help in reducing the cost of these towers.

For this study, several analysis tools in ArcGIS were chosen and identified as applicable. The main tools used in this project are Euclidean Distance, Average Nearest Neighbor, Raster Calculator, Raster to Polygon, Intersect tool, and Viewshed Analysis. Several articles that used density surface analysis to measure how much of an entity is within a fixed amount of space, guided the selection of these tools. For example, the article "Generating and mapping population density surfaces within a geographical information system" (Langford and Unwin 1994).

This research is intended for use by any college or university authorities charged with campus safety. It is expected to help them identify the locations that need more, or less, blue light emergency towers. This will assure the safety of their students and help them be confident that all areas are covered with these towers.

## Problem/Project Definition

The existence of blue light emergency phone towers is essential in any university campus to assure the safety of students, staff, faculty and neighbor around the campus. However, the optimal location and distance between these towers is important and needs to be established. Ascertaining this will help in effectively utilizing the towers and will also minimize the cost of maintenance.

The goal of this study is to determine, by the use of GIS, the appropriate distance between the towers based on the area size for each of the seven campuses at the Claremont Colleges (located in the city of Claremont, California). In addition, it aims to visualize the areas that are covered by these towers compared to the areas that are not covered and then calculate percentage coverage.

The research question is:

1. How can GIS technologies help in decision making when locating blue light emergency phone towers around collages campuses?

## Data Selection and Acquisition

Blue light towers locations and campus boundaries from a previous project were used in this study. However, in the interim, new towers were added. In the previous study, Pitzer College towers were not collected. For this study, these tower locations were collected as well as a few new towers across the other campuses. The towers were collected using Collector for ArcGIS by Esri and were added to the existing data. The previous dataset was published online and then these new points/towers were added, that is, the new data were merged with the earlier dataset.

In addition, the Los Angeles County building footprints layer, that is provided by Los Angeles GIS Data Portal was used to extract a Claremont Colleges building map. The tower location data was then placed on top of this layer to visualize their location in each campus. A light gray map was used as a basemap for the GIS web app that was created for the data collection.

## Methodology

To answer the research question the researchers have used several GIS technologies. Different analyses were used to show how GIS can help in decision making when locating the towers. All the analyses were conducted using ArcGIS Desktop. For the online visualization, ArcGIS Online was used along with ArcGIS Online Scenes (3D map representations). However, other procedures were also considered before the analysis. All the layers were converted to feet as the measurement unit to make sure that the tools work correctly and give accurate results. In addition, the boundaries from the previous study were edited. The previous boundaries had some free spaces between the campuses. Therefore, a boundary of the whole Claremont College was first drawn and each campus's boundary was broken down into smaller parts. This was done to ensure that the boundaries are connected and that no free spaces were created. Three different analyses were carried out; the first analysis was done to visualize the existing blue towers, the second analysis was performed to visualize the blue towers after relocation, and the third analysis was performed to show the Viewshed results for the existing blue towers.

In the first analysis, Euclidean Distance (ED) tool was used. The ED is usually used to show the distance between two points in a colorful way and then indicates the maximum distance or predefines the raster

("Euclidean Distance in ArcGIS" 2015). In this study, the ED was used to indicate the furthest distance from each tower throughout the Claremont Colleges whereby the boundaries of the colleges were used to define the maximum distance. The towers layer was chosen to run the analysis. The classification of this analysis was in equal intervals whereby each and every class had an equal range interval. However, the values were manually changed to delete the decimals and make the numbers easy to read and interpret.

After the analysis, the Average Nearest Neighbor tool was used. This tool is used to measure the distance between one point and its nearest neighbor, and then calculates the average distance between all the points ("How Average Nearest Neighbor Works—ArcGIS Pro | ArcGIS for Desktop" 2016). In this study, the Average Nearest Neighbor was used to generate a report to show the average distance between the towers. This result is essential for conducting the next analysis.

The third tool used was the Raster Calculator. The Raster calculator is used to execute algebraic expressions, especially when having multiple tools or operators in one regression ("How Raster Calculator Works—Help | ArcGIS for Desktop" 2016). This tool was used to visualize the distance between the towers which were within the average distance obtained from the report generated from the previous analysis. The result of this tool is a layer that shows (01) with two colors whereby0 is for the areas with the average distance and 1 is for the areas that are beyond the average distance.

The fourth tool used is the Raster to Polygon tool which is used to convert a raster layer to polygon ("Convert ArcGIS Raster to Polygons" 2016). In this study, this tool was used to convert the raster layer that had been generated from the previous tool to enable the researcher make some statistics and summaries for the number of areas that are covered with towers and areas that are not covered in each campus.

The fifth tool was the Intersect tool. The intersect tool is used to compute intersections in input features, that overlap in all layers ("ArcGIS Desktop Help 9.2 - Intersect (Analysis)" 2016). Before running this tool, the boundaries of Claremont colleges were used as a mask to define the areas to be included in the report. The Intersect tool that was used in this study was employed to show the areas of the campuses that are covered/not covered with towers in each campus. The output of this tool is 0 and 1 whereby 0 shows the areas that are covered while 1 shows the areas that are not covered.

Lastly, a summary for the areas that are not covered with towers was created in percentage form. This involved creating a summary of the Claremont Colleges campuses areas which generated a table. In addition, a summary of the areas that are beyond 250 feet from the intersect was performed to find the results of each and every campus. The two tables that had been generated were then integrated by the college field. A new field was then added to the table and the field calculator was used to calculate the percentage of the areas that are beyond 250 feet. In each campus, the area that is beyond the 250 feet mark was divided by the area of the total area of the campus and then multiplied by 100. The results of the field calculator were then added to the map to show the percentages of the areas not covered with towers in each of the campuses in Claremont Colleges.

In the second analysis, some of the towers that were too close to each other were relocated to campuses that have fewer towers. After the relocation, the above tools were then used except for Euclidean Distance (ED) and the Average Nearest Neighbor tools. This is because the same average distance from the first analysis had been used. This was done to make a comparison between the two maps (before and after the relocation).

In the third analysis, the Viewshed Analysis was performed for the existing towers in each of the campuses. The Viewshed Analysis allows the researcher to calculate the areas where the objects that can be observed can be seen, e.g. Towers. ("Perform a Viewshed Analysis—I Can See for Miles and Miles | ArcGIS" 2016).

All the analyses mentioned above were then shared to a server to be used in creating GIS web maps and later on, the online ArcGIS maps were used to create web maps. Two web maps were created; one for the first analysis and the other for the second analysis. The layers of the analyses were added by using the URL of the servers where they were being published. After creating the two web maps, a GIS web app was developed using a template for web map comparison to compare the two analyses. In addition, a GIS web scene was created to show the buildings of Claremont Colleges in 3D and the resulting layer of the

Viewshed Analysis was then added to the scene by using the URL layer from the server. The Viewshed resulting layer had to be converted to a polygon so that it could be added to the scene.

In addition to these web apps, we have created a hosted feature layer that we have used to build a web app for data collection. This web app enables the faculty, staff and students of Claremont Colleges to report any areas that require blue towers and also can be used to report out-of-order blue towers that need to be repaired.

All the GIS web apps that we created were shared publicly. We have also created a story map from a journal template that will be used to share all the apps in one place which will make the access to the GIS web apps much easier.

## Results/Discussion

The result of the towers locations, campuses boundaries, and buildings can be seen in figure 1. A color ram was used to give each campus a color in order to make it easy for them to be located and visualized. The first tool was Euclidean Distance (ED). Figure 2 shows the distances in feet from each tower whereby each distance range has a different color. This analysis shows the furthest distance from the towers in each campus. From this analysis, it is clear that some colleges have very good distances between the towers to cover the campus area, while the distance between the towers in other colleges is quite far. The Towers in Scripps College, Claremont Graduate College, and Harvey Mudd College portray the most appropriate distance through the whole campus. The furthest distance from the towers is between 157 – 314 feet which can be seen in the yellow and orange color. The remaining colleges have much longer distances from the towers and it is important to note that in Pitzer College and Claremont McKenna College these areas are mainly sport fields/car parks. However, the distance between the towers is still very long and the colleges require at least one tower, because bad situations can happen in the sport fields/car parks. This analysis can help authorities to determine the areas that are far away from the towers and install some towers in those locations.

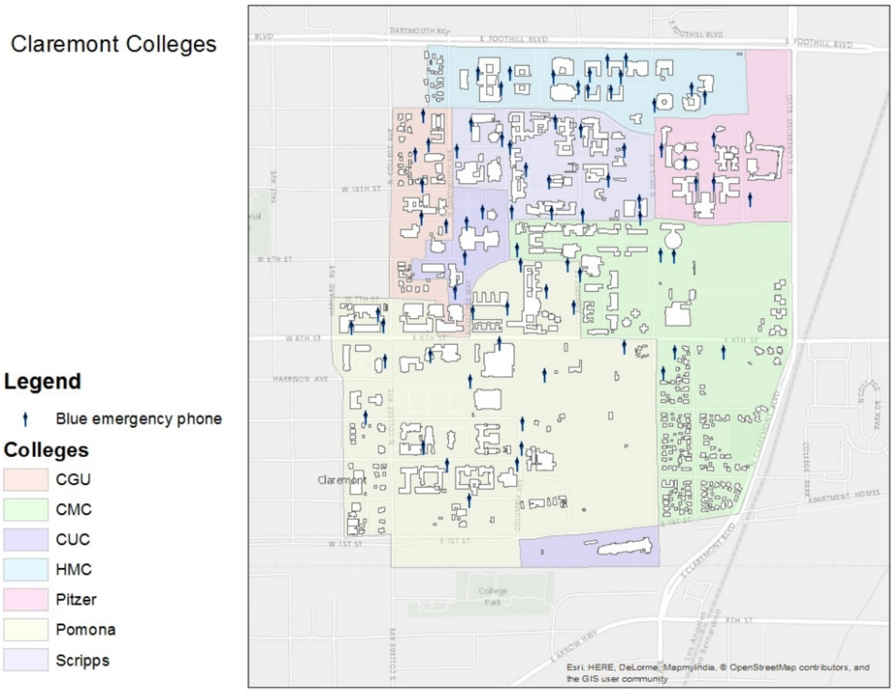


**Figure 1. Colleges boundaries and Towers location.**

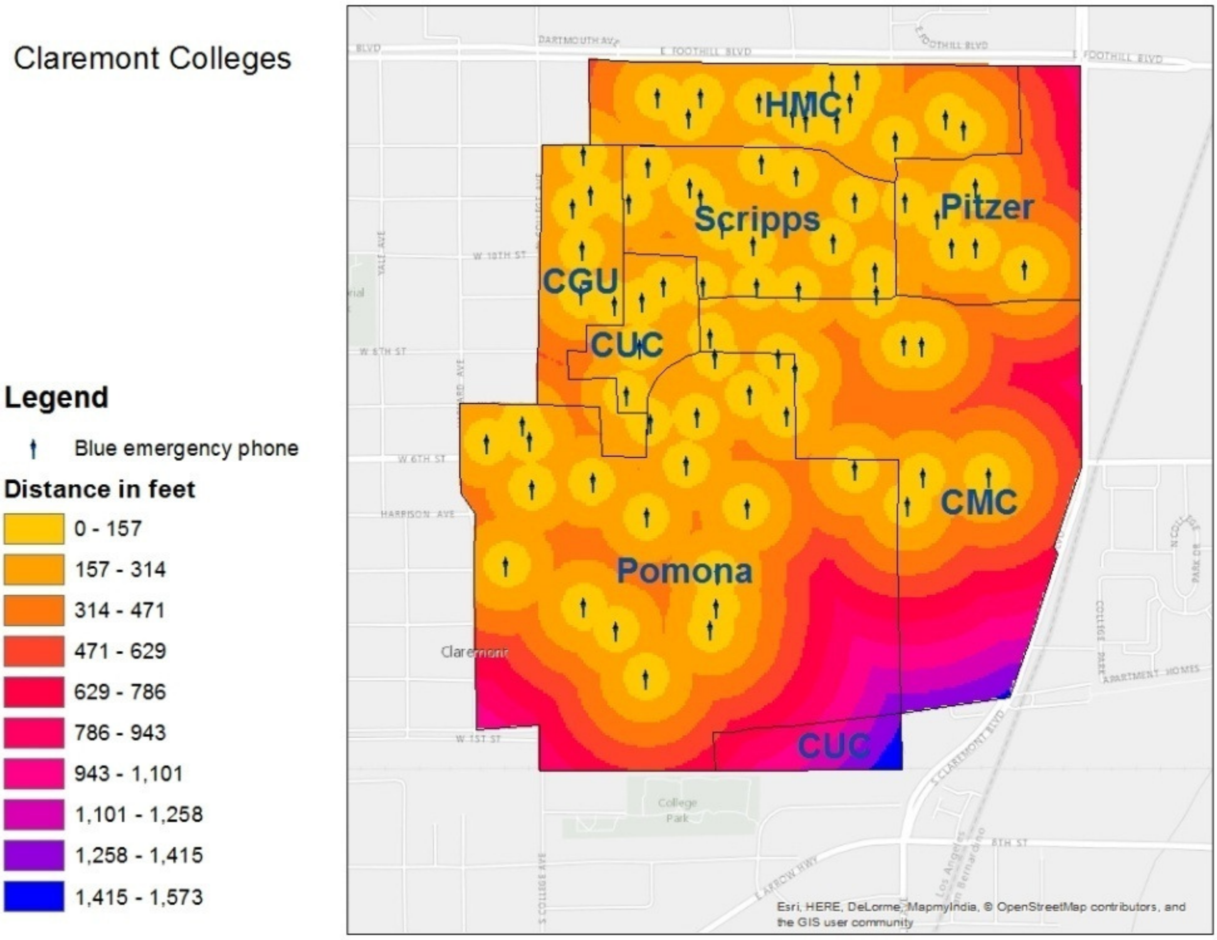


**Figure 2. Distance from each tower in feet for each campus.**

After determining the distances from each tower, the Average Nearest Neighbor tool was used to calculate the average distance between the towers. In the Raster Calculator tool, the average distance, which was around 250 feet based on the report, was used to visualize the areas that are within the average distance and the areas that are beyond the average distance. Figure 3 shows the result of the Raster Calculator tool. The yellow areas are the areas within the 250 feet and the purple areas are the areas beyond the 250 feet. Most of the areas within the colleges are within the 250 feet except for Pomona Colleges and Claremont McKenna College which have a number of areas that need installation of some towers. The Authorities in the area can use some of the towers that are very close to each other and relocate them to Pomona Colleges and Claremont McKenna College.

The Intersect tool produced a layer that shows the areas that are not covered by towers in each campus. The areas with stripes are the areas that are not covered with towers as seen in figure 4. In summary, Scripps Colleges was the best college regarding the coverage whereby only %6.7 of the area is not covered with towers. On the other hand, Claremont McKenna College is the college that has the highest area that is not covered with towers (%68.3).

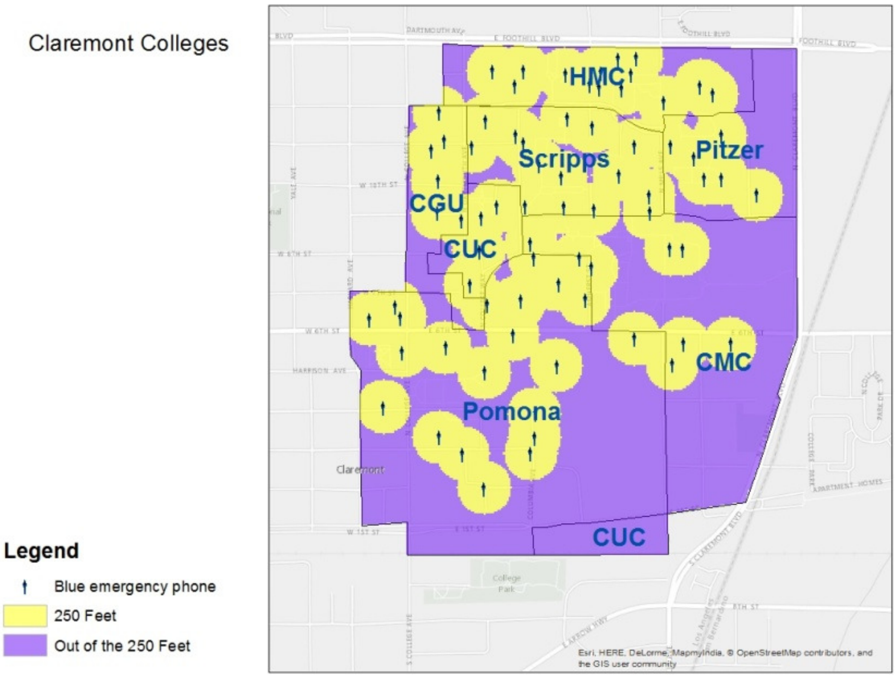


**Figure 3. The areas within and beyond 250 feet in each campus.**

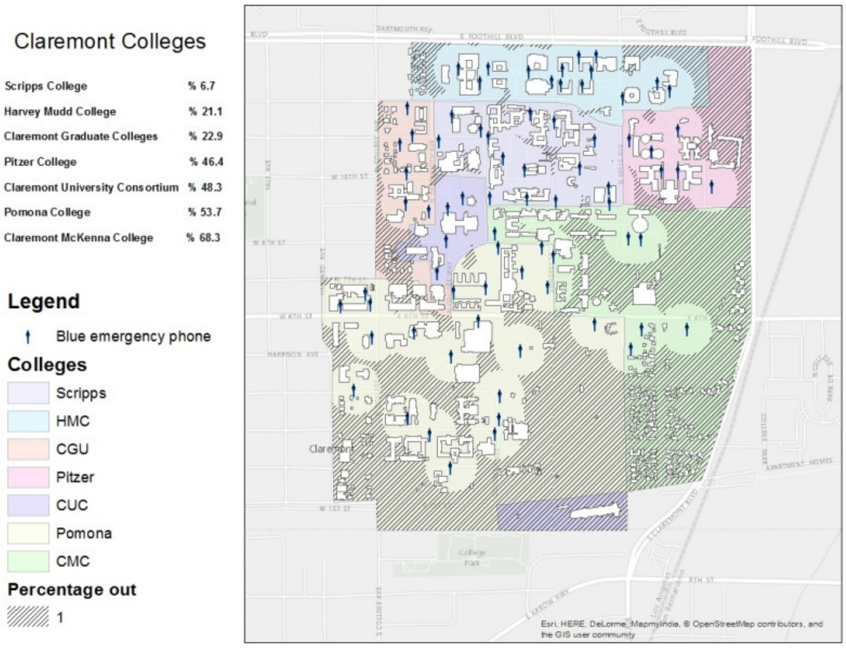


**Figure 4. The areas that are not covered with towers.**

The above steps were followed for the second analysis. Both analyses were shared in a server and two GIS web maps were created using online ArcGIS whereby a web app was created to compare the two analyses. Figure 5 shows a screenshot of the GIS web app that compares the results of the two analyses. After relocating the blue towers, the percentage of the areas that are not covered by blue towers has declined. For example, Pomona College in the first analysis had 53.7% of its total area not covered by towers, but after the relocation in the second analysis, the areas that are not covered decreased to 46%. Some of the blue towers that were used for relocation were taken from Scripps College and the results show that even though some blue towers from the college were used, the college did not suffer from dramatic increase in the areas that are not covered by the blue towers. This is because the college has more than enough towers and the towers were very close to each other. The percentage of the areas that were not covered in the first analysis for Scripps College is 6.7%, and in the second analysis it increased to7%. The URL for this app is; http://agis.maps.arcgis.com/apps/CompareAnalysis/index.html?appid=2a51a1cf6fcf4589a072772034aa274e.

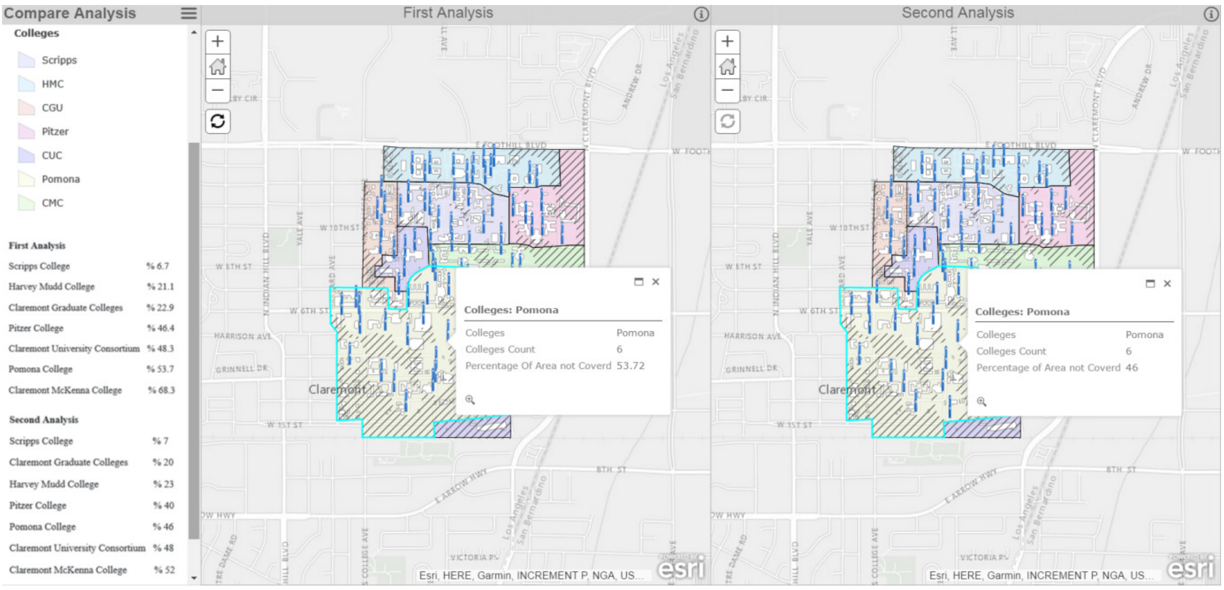


**Figure 5. A screenshot of the comparison GIS web app.**

The second app that we have created is a GIS web scene that shows the buildings of Claremont Colleges in 3D. We have used the building layer of Claremont Colleges to visualize the buildings in 3D. We have also added the Viewshed resulted layer in the scene to show the areas from where the blue towers can be seen and the areas from where the blue towers are blocked. Figure 6 shows a screenshot of the GIS web scene for the Claremont Colleges. The green color represents the areas from where the blue towers can be seen from while the red color represents the areas where the view of the blue towers is blocked by the buildings. The slides at the bottom of the app show different views. The URL for this web app is http://agis.maps.arcgis.com/apps/webappviewer3d/index.html?id=cfa644edcfea4300abb56b4995a06f49.

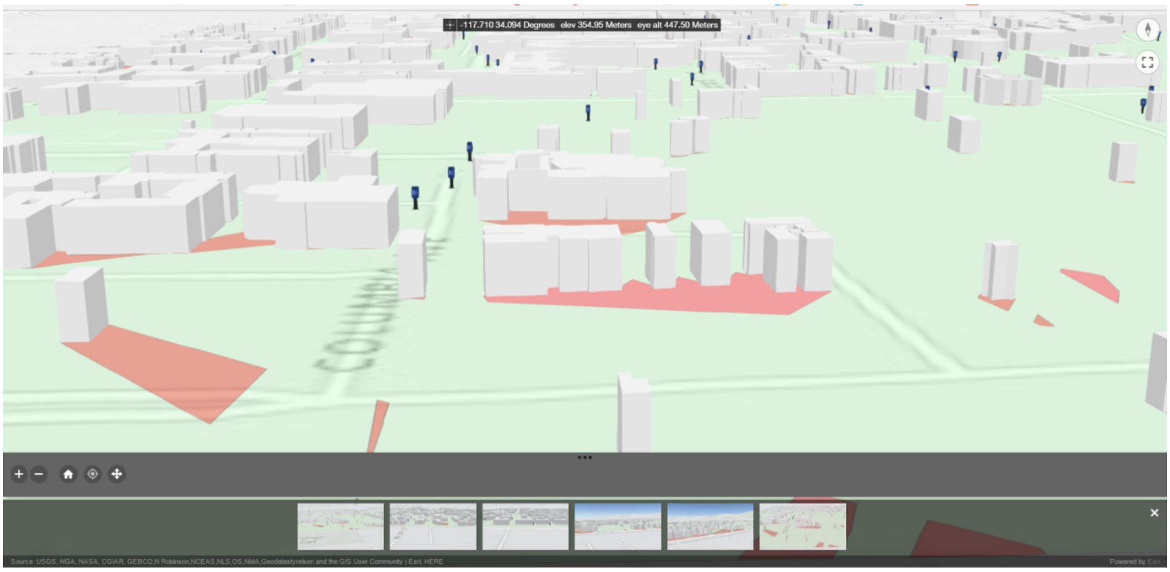

**Figure 6. A screenshot of the GIS web scene app.**

The third GIS web app that we created is a form that uses a hosted feature layer to report the locations that needed blue towers or the blue towers that are out of service. This web app collects information about the incident. It includes a brief description of what the report is about, date of reporting, reporter's name, reporter's email or phone number, attachments, and selecting the location. After submitting the information, it will then be added to the web map. The URL for this GIS web app is http://agis.maps.arcgis.com/apps/GeoForm/index.html?appid=077aa1ad473e4d46877d148f44c6f036.

All the GIS apps that are mentioned above were grouped into one Journal Story Map, which gives an easy access to all of our GIS web apps. It starts with the home page that has the details about the project and three other pages one for each web app that we have created. The URL for this story map is http://agis.maps.arcgis.com/apps/MapJournal/index.html?appid=e6c519bfd5934eebb3f674c3b73183a6.

## Conclusion

The blue emergency phone towers are very important and therefore, they should be created in each university campus. It assures the safety of students, staff, faculty, and neighbors around the campuses. Determining the locations and how far the towers should be from each other is also equally important, which was the main focus of this study. The results show that some campuses in the region need some additional towers and since some campuses have more towers than they really need; these can be relocated to the campuses that need the towers. This will reduce the cost and authorities will not need to buy new towers, which are very expensive. The Viewshed Analysis helps in determining the best location to install the blue towers in order to avoid installing them in areas where the view can be blocked by buildings. This being said, the advancement in technologies might limit the use of such towers in the future. This could limit the generalizability of the proposed solution.

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