MEA582-601 Fall 2014 Dunlop, Kevin

Paper: Highway to Airfield Identification

Introduction

Figure 1: Expressway 1 in South Korea, which has a built-in airfield. Military planes are practicing landing and taking off from it during an exercise.[7]

Runways are permanent features that must be constructed following strict regulations. In very dense areas like South Korea, finding locations where runways can be placed without violating these regulations, such as airspace restriction, is difficult. This is especially true in war time and natural disaster situations, where temporary runways are needed. During these events, features such as expressways may be converted into temporary runways. While it is a myth that the US interstate system was designed to allow certain sections to serve as runways[8], South Korea has used expressways as runways in the past, as Figure 1 depicts. Runways require long, straight, flat, and level surfaces in order for planes to land safety. In addition, the presence of tall buildings and trees next to expressways will limit the placement of runways. While in some instances, these airspace violations can be waivered, the ideal solution is to find areas without any violations. My project focuses on developing a methodology for finding suitable locations for temporary runways along an expressway/interstate system that have the fewest violations.

Study Area

While this project is designed to develop a methodology for locating suitable locations for temporary airfields, the sensitive nature of the possible military airfield locations and limited available GIS data in South Korea precludes me from using solely South Korean data for this project. Instead, I decided to use a 20ft resolution DEM and interstate feature class for Wake County, NC, and buildings from Gunsan City, South Korea. Without changing the footprint or size of buildings, I moved them to align with the interstate system in Wake County. This method allowed me to use real Korean building footprints and layouts without violating any security issues.

Five test sites, shown in Figure 2, were selected that had at least 5,900ft of relatively straight road with no overpasses. This length was chosen because it is the required length for elevation range and temperature (85°F) of the area for a Class A runway[1]. These sites were selected manually, since I was unable to utilize an automatic method[2] of detecting straight segments of roads.

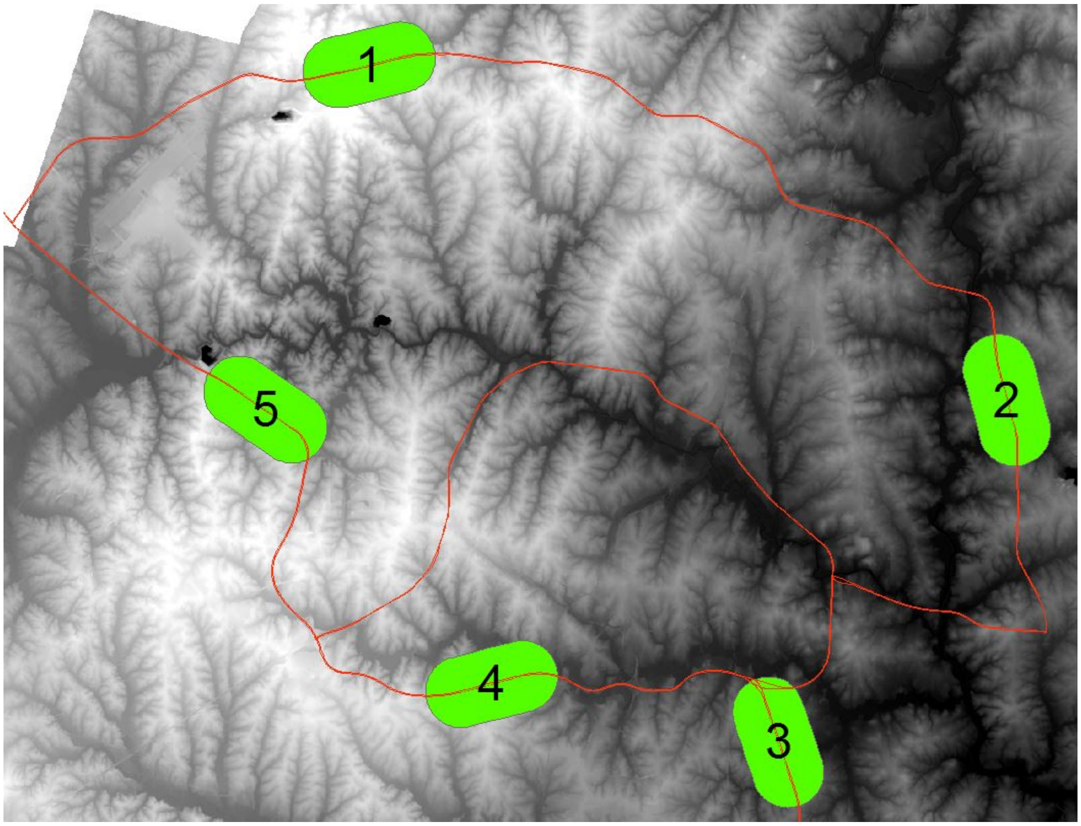


Figure 2: The five test sites used in this project. All sites are 5,900 feet long with no overpasses or bridges.

Data

The data used for this project came from two sources. The DEM and interstate data came from NC One Map's website,[5] while the building data came from the GeoBase Office of Kunsan Air Base. The DEM and interstate data was in NAD83 State Plane NC, FIPS 3200, Feet. The building data was in WGS84 UTM 52N, Meter. The interstate data was in a shapefile format, and the building data was a feature class inside of a file geodatabase. In order to keep all data together and preserve the original data, all vector data was imported into a new file geodatabase.

In order to align the buildings with the test sites, I changed the project on the buildings to be NAD83 State Plane NC FIPS 3200, Meter. Next, I moved the buildings to overlay with the interstate data. Finally, in order to keep all data consistent, I projected the buildings to use the same projection as the North Carolina data.

Methodology

The first step was to identify the test sites. These sites were selected manually, since I was unable to utilize an automatic method[2] of detecting straight segments of roads. The basic requirements for each site were to be 5,900 feet in length and to have no bridges or overpasses, which would interfere with take offs and landings. The interstate centerline for each site was clipped and imported into a polyline feature class.

For Step 2, since I did not have the footprint for the pavement of the interstates, I buffered the polyline feature class created in Step 1 by 35 feet. The polygons generated by the buffer represented the temporary runways' footprints. 35 feet was selected by measuring the width of the interstate, including the shoulders, for one of the sites in Google Map's Aerial imagery. The measured width was 70 feet, which gave me the 35 feet because the buffer was applied to both sides of the centerline.

Step 3 involved calculating the slope for the DEM raster. Since the test sites need to be flat and level, statistics for the slope under each of the test sites' footprints was generated as the next step. The main focus was on the mean, range, and standard deviation, which indicated the flatness and levelness of the interstate section.

Next, the buildings for Gunsan City were moved to align with the site tests. Different building density and layout were used for each of the test sites. These layouts are commonly found along expressways in South Korea. Figures 3-7 show the layouts for each test site.

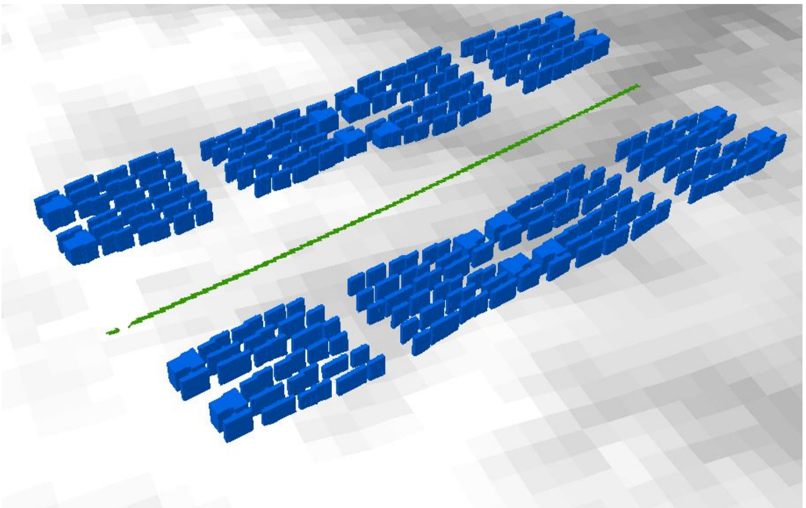


Figure 3: Test site 1 uses same height buildings with identical layouts on either side of the highway.

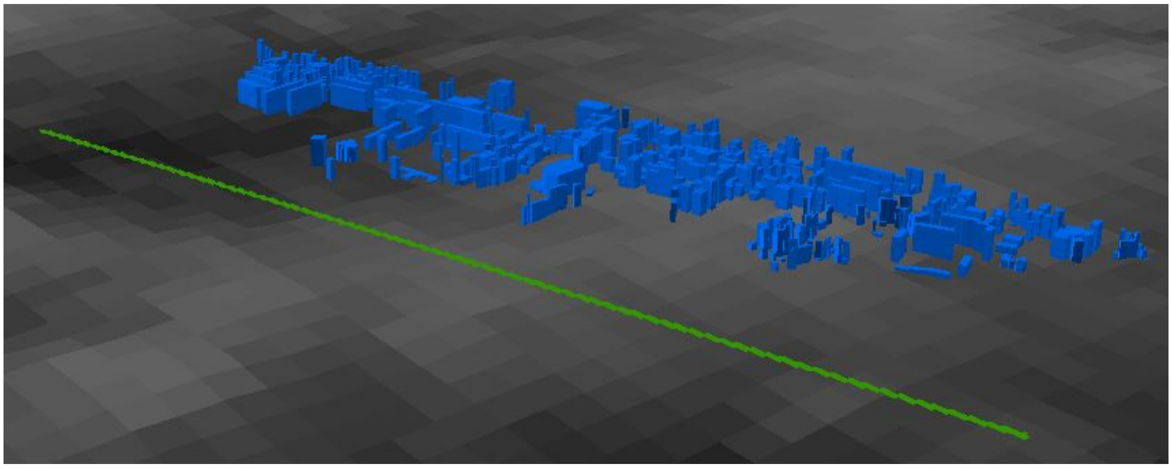


Figure 4: Test site 2 uses mixed height buildings on only one side of the highway

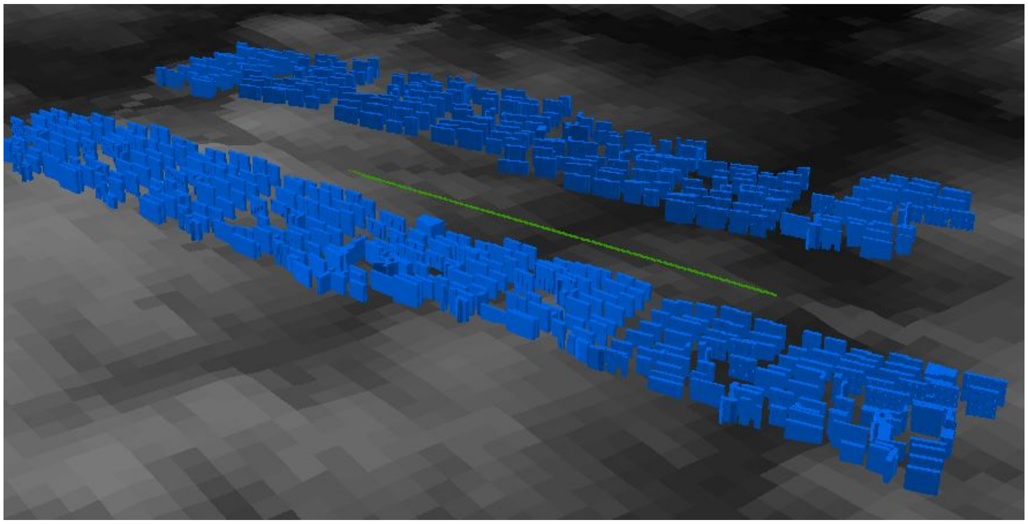


Figure 5: Test site 3 is a dense set of apartment buildings with mixed heights in a non-standard layout.

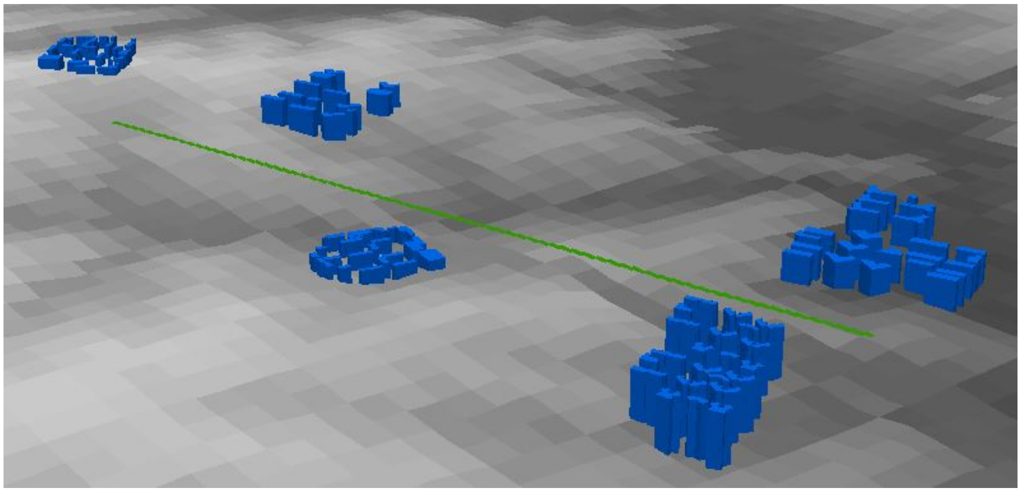


Figure 6: Test site 4 uses several small- to medium-sized clusters of buildings. Some clusters have uniform heights, while others have mixed heights.

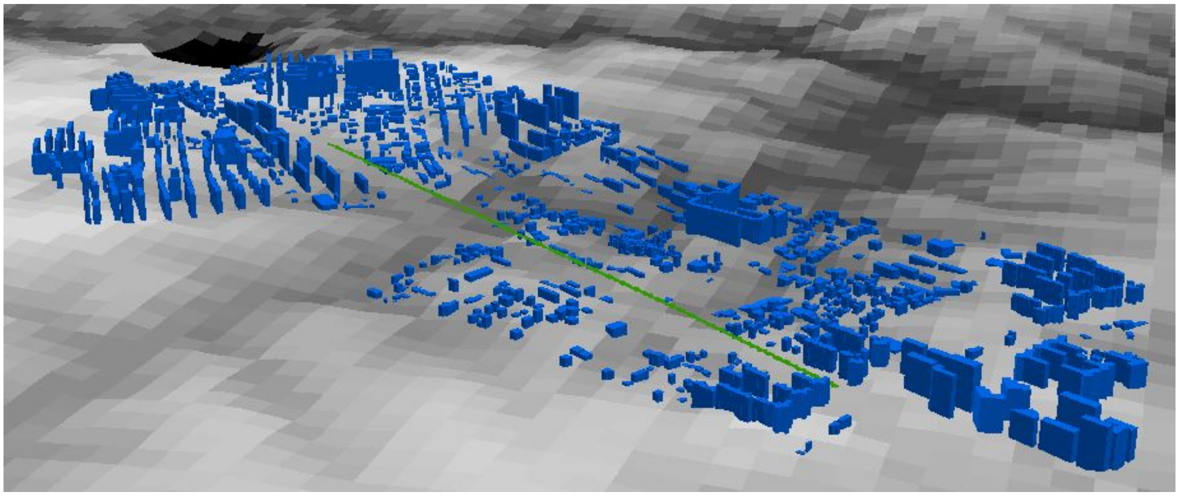


Figure 7: Test Site 5 represents a small site with a highway running through its center. Buildings have mixed height.

Airspace restrictions, also referred to as airfield imaginary surfaces, require them to be calculated using the highest elevation on the runway[1]. Therefore, the maximum elevation was determined for each of the test sites using the DEM. Table 1 shows the values and will be referred to as ground level from this point onward.

Table 1: Maximium elevation for each of the test sites

Test Site	Max Elevation (feet)
1	495
2	282
3	268
4	383
5	400

The next step was to draw the airspace restrictions based on the requirements for Army Class A runway. The z-enabled polygons for these restrictions were categorized into three types: 500ft Clearance, Approach Zone, and 7:1 Clearance. The 500ft Clearance was a 500ft buffer of the centerline with square ends at ground level. The Approach Zone fanned out from the ends of the runway at a deflection angle of 82° and had a 40:1 ratio. The 40:1 ratio means that, starting at ground level at the edge of the runway, the z-value gains 1ft in height for every 40ft traveled on the ground. The approach zone is 10,000ft long. The 7:1 Clearance is on either side of the 500ft Clearance area and has a 7:1 ratio similar to the 40:1 ratio. There is no maximum distance of the 7:1 ratio, but I took it out to 2,100 feet, which resulted in a z-value greater than my tallest building.

Step 8 was to display the DEM, the test sites, the buildings, and the airspace restrictions in a 3-D environment. The buildings were set to use the base height of the DEM. Since they included only the number of floors and not the height, the buildings were extruded using a multiplier of 3.1m, which is the average height for a residential/hotel floor-to-floor height[3]. This resulted in the buildings being displayed as 2.5-D features. In order to overlay the sites with the 500ft Clearance areas, the test sites were set to display using the maximum heights as described in Table 1. Since the airfield restrictions were already a 3-D object, no additional modifications needed to be made to them. A vertical exaggeration of 2 was applied to the 3-D environment.

The last step was to identify the buildings that intersected the airspace restriction zones. Since the software I used does not allow 3-D location based selections on 2.5-D features, a manual visual inspection was performed, and the quantity/severity of the violations were categorized as green, yellow, and red.

Results and Discussion

When selecting my five test sites, I realized that I had made several false assumptions in my initial planning. The first assumption was that the interstate system in Wake County and the expressway system in South Korea would be roughly the same in design. However, I discovered while taking my width samples to determine the width of the interstates that most of the straight sections in Wake County have a grass median, which therefore limited me to using only one side of the interstate. In South Korea, most expressways have only a removable concrete barrier that divides the opposing directions of traffic. This difference resulted in a narrower width for the interstates in Wake County, compared to the expressways in South Korea. For example, a 6-lane highway (3 lanes in each direction) would only have 3 lanes usable in Wake County, while the expressway in South Korea would be able to use all 6 lanes. As I mentioned in the data section, the average width I found was 70ft. However, the military regulation UFC 3-260-01 calls for 100ft minimum width, thereby excluding all test sites in Wake County but not in South Korea.

Another false assumption was that I could use the full length of straight sections. It did not occur to me prior to this project that there may be overpasses for these sections. Typically, US interstates go under other roads, while Korean expressways go over most other roads. My original plan called for test sites that can support a Class B runway, which is a longer runway than a Class A runway. Class A runways cannot handle large, heavy aircraft like cargo planes, but a Class B can. However, because of the overpasses, I was limited to the shorter Class A. Korean expressways are generally straighter than US interstates.

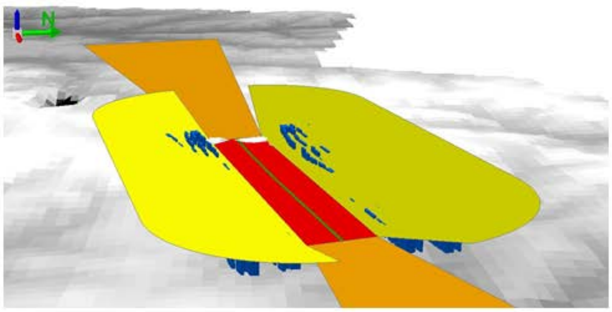
Even with the requirements for width and length excluding all possible sites in Wake County, I have decided to acknowledge but ignore them because my project focuses on the flatness of the runway and the impact that buildings on either side of the runway have. A 5,900ft runway is long enough to give a good test site for flatness and levelness, and the clearance zones are based on the centerline of the runway, not the edge of pavement. My results should be similar to the results that I would get if I could use Korean expressways and the correct size for the test sites.

Table 2 below shows the slope statistics generated for the five test sites. Since a flat surface is ideal, a mean value close to zero was desired. Likewise, a level surface is also necessary for the safety of aircraft landing and taking off. A small range and standard deviation represented a level surface and was desired. I ranked each of the test sites with these criteria in mind. Test site 3 was the most promising site, while test site 1 had the worst statistics. However, only an airfield engineer would be able to determine if the differences between these statistics represented a grave enough risk to exclude a test site outright.

Table 2: Slope statistics for the test sites

Site	Mean	Range	Standard Dev	Ranking
1	5.02	27.81	6.10	5
2	3.50	10.82	1.71	2
3	1.85	15.26	1.69	1
4	2.01	20.55	2.01	3
5	3.24	36.08	3.96	4

The next set of results, pictured below as Figures 8-12, show the airspace violations. Any blue building showing through the top of the airspace restriction zones was considered in violation. Buildings below the zones were acceptable and did not cause a violation. The quantity and severity of the violations were categorized using a green, yellow, red system. Since this categorization was a manual process, the resulting values were based solely on my personal opinion. This process of categorizing the violations should be formalized and defined better in order for this methodology be used at a later date. Special focus was given to violations in the 500ft Clearance zone and Approach zone because they impact aircraft operation significantly more than violations in the 7:1 Clearance zone.



Zone	Violations
500ft Clearance	None
Approach	None
7:1 Clearance	Moderate

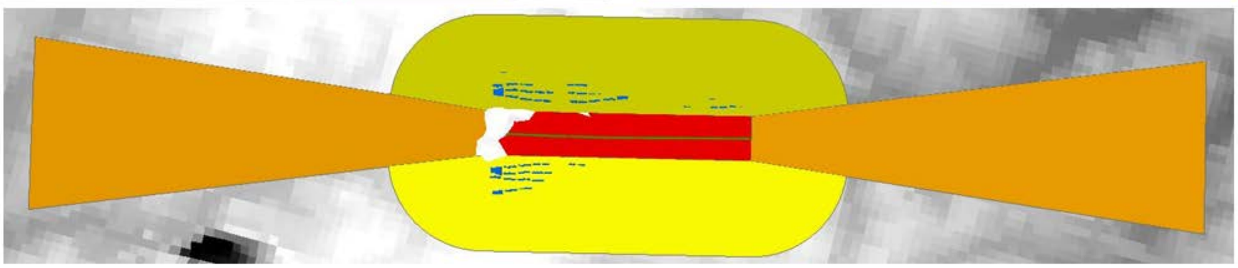
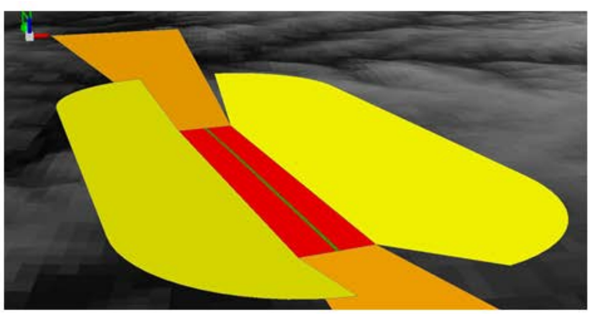


Figure 8: Test Site 1



Zone	Violations
500ft Clearance	None
Approach	None
7:1 Clearance	1

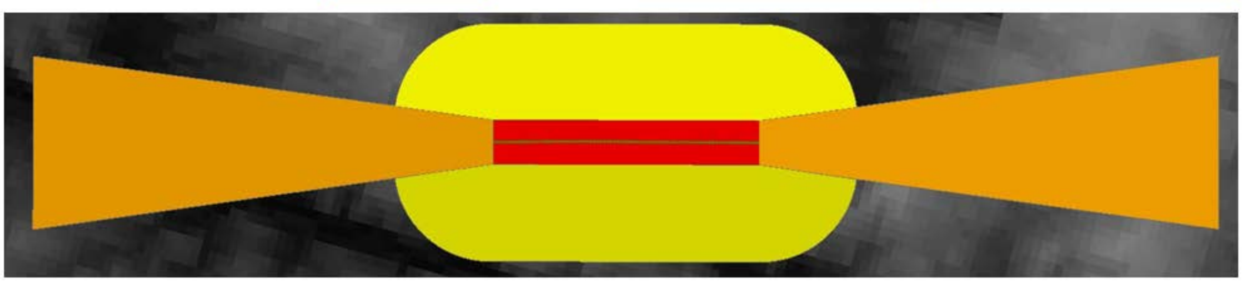
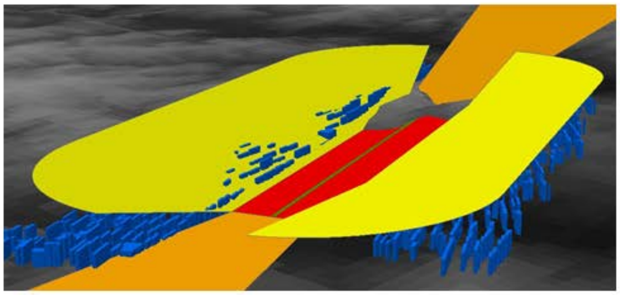


Figure 9: Test Site 2



Zone	Violations
500ft Clearance	None
Approach	None
7:1 Clearance	Moderate

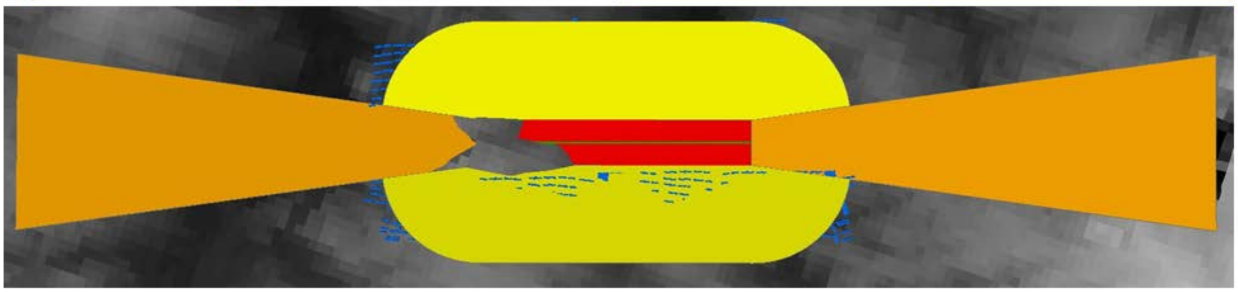
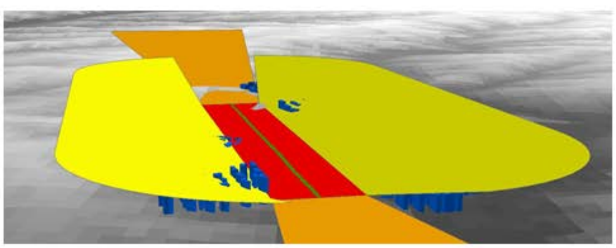


Figure 10: Test Site 3



Zone	Violations
500ft Clearance	Limited
Approach	Limited
7:1 Clearance	Moderate

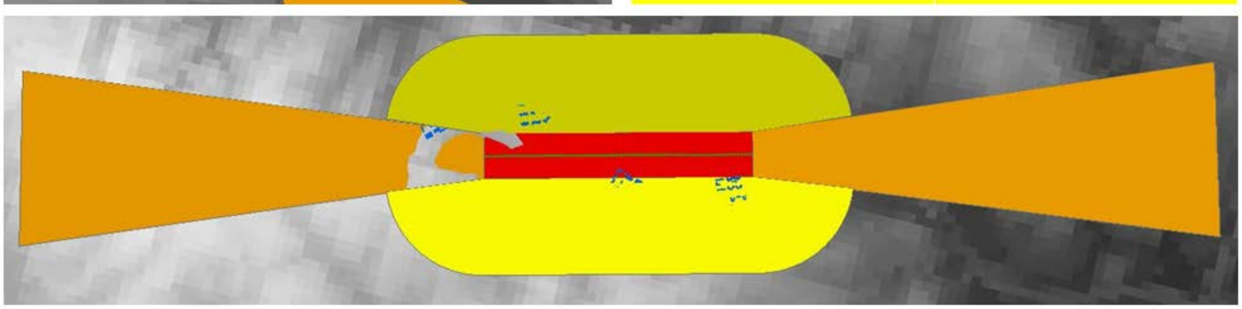
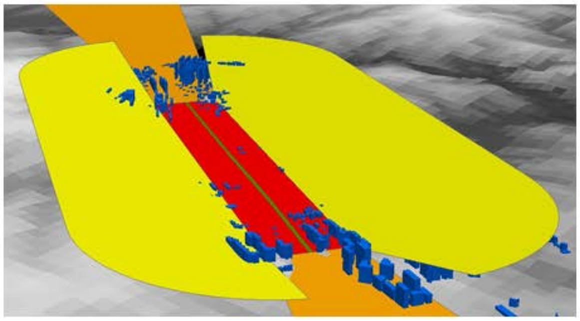


Figure 11: Test Site 4



Zone	Violations
500ft Clearance	Severe
Approach	Severe
7:1 Clearance	Moderate

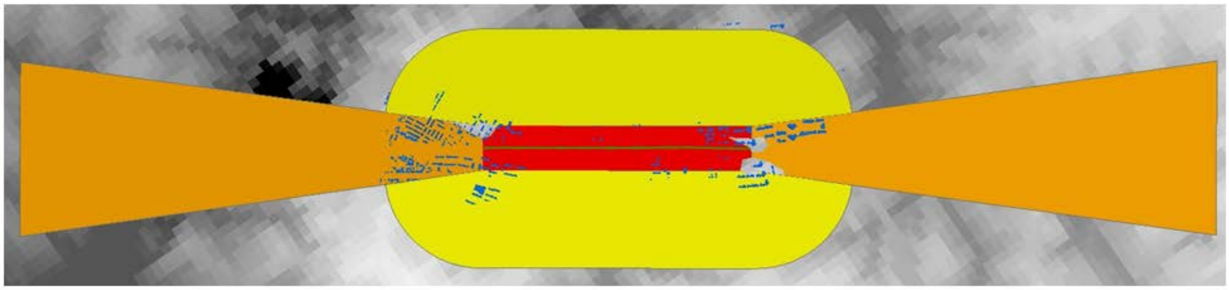


Figure 12: Test Site 5

Table 3 shows the summary of the results for the slope statistics and airspace violations. As the table shows, test site 2 was the best site overall, having a good slope and levelness and only one airspace violation. Test site 5 had a poor slope ranking and significant airspace violations. While the situational ground commander would make the final determination of which test site to convert into runways, my recommendation would be to use the first three test sites and possibly the forth test site, if required. However, I would also recommend to the commander that the fifth test site be excluded.

Table 3: Summary of the slope statistics and airspace violations

Test Site	Slope Ranking	500ft Clearance	Approach	7:1 Clearance
1	5	None	None	Moderate
2	2	None	None	1
3	1	None	None	Moderate
4	3	Limited	Limited	Moderate
5	4	Severe	Severe	Moderate

Conclusion

The methodology developed during this project has proven to yield valuable preliminary results which can exclude unsuitable sites and identify promising site for temporary runways. However, there is much future work required in order to develop this project into a useful tool that can be utilized in emergency situations. The first step would be to test it on real world data from only one location, such as South Korea. Since I manually moved and placed the buildings and did not have an actual pavement footprint, this process may not have been as effective with real world data.

Secondly, additional features, such as trees and utility poles, should be included in this model. I believe that these features can be identified with LIDAR data. The inclusion of this information may result in currently identified suitable sites becoming unsuitable. For example, if test site 2 had a forest on either side of the highway, the site would have too many airspace violations to be acceptable.

As mentioned in the results section, the categorization of the airspace violations was done manually and can therefore result in bias errors. This process should be standardized with well-documented guidelines, outlining what is considered to be green, yellow, or red.

Pavement quality will also impact the suitability of the test sites. Poorly maintained roads can cause pebbles and other foreign object debris (FOD) to be sucked into an engine, resulting in significant damage to the aircraft. Therefore, pavement quality should be included in the analysis.

Lastly, an automatic process to identify straight, long segments of roads needs to be developed and implemented into the methodology. Compared to the manual identification process, the automation will decrease the amount of time required and increase the accuracy of the site identification process, especially over large study areas like a whole state or country.

Overall, this project was successful and is the first step in a formalized process of automatically identifying and rating temporary runway locations.

References

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