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| CVEN1501 OPTIMIZATION FOR ENGINEERS: PROJECT 1 | **Flood Potential Across Texas using TOPSIS; Ranked by counties.**  Submitted BY: Group 4  Deseyi D John  Kushum K C  Mason Z Wyche  Minhajuk Abedin Tajik |

# Introduction (motivation for choosing the topic)

Flooding in Texas is a major problem that has plagued the state for years. It is true that some counties are more vulnerable to floods than others. Much attention in the analysis in the project has not been paid to any type of flooding (flash flood, River flooding, dry wash). Various counties in Texas, due to their geographical location amongst other factors make them susceptible to various flood types. Regardless of the type of flooding that occurs, the resulting damages are identical among which loss of lives and properties are the serious and unavoidable effects. For this reason, this research takes a more generic angle as pertaining to flood.

In an attempt to emphasis the reason for this study, central Texas geographical location makes it susceptible to this natural disaster. Central Texas has major storms coming from the Pacific Ocean, Gulf of Mexico and strong frontals boundaries coming in from the great plain. It is a trifecta for central Texas and sometimes the rain falls too fast for the soil to absorb it all. In 2013 was the Halloween Flood, where 9-10” of rain fell across Hays and Travis counties in central Texas. This disaster led to impact 825 homes, 40 road closures and worst of all 4 fatalities. Still in central Texas 2 years later in 2015 was the Memorial weekend flood. 10-13” rain was recorded in southern Blanco County, and it caused a devastating rise in the Blanco River. It rose from 5 feet to 41 feet in four hours, and after that it rose at a staggering rate of 5 feet every 15 minutes. This became problematic to the city of Wimberley, TX where 350 homes were destroyed and 13 people died according to spectrum local news1.

Texas cuts across 268,597 sq miles and is home to approximately 29.18million people (about the population of Texas). This verse land makes the state geography complex and for this reason, Flash floods, river systems and dry wash are some of the common types of floods that occur in Texas. And understanding of these flood types and how they occur would help explain why the data set used for this research was chosen.

# Methodology

## 2.1. Data Collection

From the better understanding on the potential of flooding and their causes in the different counties of Texas, the following criteria were considered:

2.1.1. Precipitation data (inch)

2.1.2. Distance from the coast (miles)

2.1.3. Land cover(wetland) (mean ratio)

2.1.4. County Elevation (ft)

2.1.5. Urban imperviousness (mean)

The data analysis was carried out to perform the TOPSIS (technique for order preference by similarity to ideal solution) for ranking the counties in Texas in terms of flooding potential. The evaluation is carried out for the 254 counties (alternatives) based on five sets of pre-defined criteria. For the calculation of the criteria' relative weights, two different approaches were used: first involved the use of Perron Fresenius concept adopted by AHP (Analytic Hierarchy Process) and second was the entropy method.

## 2.2. TOPSIS model using Perron Fresenius Eigen Vector (AHP)

Our group used the AHP and TOPSIS analysis methods to rank the criteria relative to our project's purpose. The project's purpose is to determine the potential of flooding across the state of Texas by county. The criteria chosen to rank each county are as follows: the elevation above sea level, precipitation data, distance from the coast, wetland cover, and finally urban imperviousness. The data was gathered from online data bases, such as the mrlc.gov. Once the criteria were determined and the data gathered, the next step was to then have them ranked against one another, on a scale from 1 to 9, using the AHP (Analytic Hierarchy Process) method of pairwise comparison, created in part by Saaty in 1980. The ranking starts from a 1, which says that the 2 criterions being ranked are of equal importance to one another, to a 9, which says that of the 2 criterions being compared, one is of much more importance than the other in the. A spreadsheet on Excel, comparing the 5 criteria, was developed, and completed internally, amongst the 4 members of the group, individually. One final spreadsheet, with the criteria rankings, was sent to our professor Dr. Hernandez, since it was decided that a professional opinion would enhance the accuracy of the analysis. After the data was gathered, the averages of the 4-group member’s pairwise comparisons were taken. After this, each averaged value was then added to Dr. Hernandez’ pairwise comparison, and then one final average was taken of all the data. The finalized data was then organized into a matrix. Then, following the Perron-Frobenius theorem, the criteria were then normalized. Normalization is done to remove bias, to a degree.  Once the normalized matrix was calculated, this data was then transferred to R Studio to do TOPSIS (Technique for Order Preference by Similarity to ideal Solution) analysis. This method of ranking alternatives, based on their distance from the ideal solution, was developed by Hwang and Yoon in 1980. After inputting the data into R Studio and allowing the system to run, a final value was assigned to each criterion, based on whether it was considered a PIS (Positive Ideal Solution, or an NIS (Negative Ideal Solution). From this, our group was able to rank the criteria, as well as the counties most likely to flood, and ultimately formulate this report with our conclusions.

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## 2.3. TOPSIS model based on entropy.

# Result and Discussions

The result of the weights from both (AHP and Entropy) processes, positive, negative benefit input, and the outcomes of the TOPSIS analysis for the alternatives is presented below.

3.1. TOPSIS using AHP.

The pairwise comparison matrix of the criteria obtained by averaging the data collected from the expert opinion and the group members opinion is presented below:

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| --- | --- | --- | --- | --- | --- |
| **Criteria** | **C1** | **C2** | **C3** | **C4** | **C5** |
| **C1** | 1.000 | 5.250 | 5.750 | 2.320 | 3.072 |
| **C2** | 0.190 | 1.000 | 1.567 | 0.409 | 1.456 |
| **C3** | 0.174 | 0.638 | 1.000 | 0.800 | 2.167 |
| **C4** | 0.431 | 2.446 | 1.250 | 1.000 | 2.000 |
| **C5** | 0.326 | 0.687 | 0.462 | 0.500 | 1.000 |

The converged dominant eigen vector obtained after normalizing the rating and performing the Perron Fresenius theorem on the pairwise comparison matrix for five criteria obtained using Excel is shown below. These values were used as the weights for the TOPSIS analysis. Also, the benefits (impacts) of each criteria have been included in the table below.

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Normalized Converged Eigen Vector** | **Impact (positive or negative)** |
| C1 (Precipitation) | 0.48 | + |
| C2 (Distance from the Coast) | 0.12 | + |
| C3 (Wet Land) | 0.12 | + |
| C4 (Elevation) | 0.19 | - |
| C5 (Urban Imperviousness) | 0.09 | + |

The rankings of the county based on the risk associated with the flooding obtained using the AHP presented Harris County to be the most flood prone county. The result showed the following map.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| |  |  |  | | --- | --- | --- | | **Rank** | **Score** | **County Name** | | 1 | 0.65682 | Harris | | 2 | 0.6339 | Jefferson | | 3 | 0.6332 | Orange | | 4 | 0.59405 | Dallas | | 5 | 0.58367 | Liberty |  |  |  |  | | --- | --- | --- | | **Rank** | **Score** | **County Name** | | 250 | 0.138 | Culberson | | 251 | 0.126 | Jeff Davis | | 252 | 0.125 | Brewster | | 253 | 0.124 | Presidio | | 254 | 0.113 | Hudspeth | | Map  Description automatically generated |

3.2. TOPSIS using Entropy.

Entropy method calculates the weight by calculating the degree of diversification of the criteria with is the complement of the entropy. The weight from entropy model obtained by normalizing actual performance (criteria) ratings and the impacts input for the positive and negative benefit of the criteria has been listed below:

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Weight (using diversification)** | **Impact (positive or negative)** |
| C1 (Precipitation) | 0.0274 | + |
| C2 (Distance from the Coast) | 0.0803 | + |
| C3 (Wet Land) | 0.3857 | + |
| C4 (Elevation) | 0.1590 | - |
| C5 (Urban Imperviousness) | 0.3476 | + |

The result of the TOPSIS analysis for ranking the county based on the potential flooding has been listed below:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| |  |  |  | | --- | --- | --- | | **Rank** | **Score** | **County Name** | | 1 | 0.637 | Harris | | 2 | 0.601 | Dallas | | 3 | 0.542 | Tarrant | | 4 | 0.471 | Orange | | 5 | 0.452 | Jefferson |  |  |  |  | | --- | --- | --- | | **Rank** | **Score** | **County Name** | | 250 | 0.041 | Culberson | | 251 | 0.034 | Presidio | | 252 | 0.034 | Brewster | | 253 | 0.033 | Jeff Davis | | 254 | 0.033 | Hudspeth | | Map  Description automatically generated |

From both the obtained weights, on the given data TOPSIS analysis resulted comparable results. The map obtained by plotting the rank clearly depicts that the counties at the southern part of Texas have higher potential of flooding than the northern part. Harris County that lies in the eastern part of Texas, has been ranked number 1 indicating the higher probability of being flooded compared to other counties under the given criteria. Ghebreyesus, D. et al. (2020) had the conclusion that the eastern portion of Texas (east of Houston metropolitan area) has the highest average annual precipitation, which also validates our ranking result. Also, the elevations at the southeastern part of Texas are low and lands are flat compared to those of the northern portion and the southeastern part are closer to the coast (either Gulf of Mexico or the North Pacific Ocean) so these areas have more risk of being flooded. Also, the land use/ land cover data when overlayed over the rank map indicated that the potential of flooding is higher at the areas having more developed lands reflecting the higher urban imperviousness.

The Dimmit County at the lower mid portion of Texas have less precipitation compared to immediate neighbor counties, also the mean ratio of the developed land is less i.e., the less urban imperviousness, so the potential for the flood event to occur is less in this county with respect to neighboring county.

# References

The references used for collecting the data are listed below:

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| **SN** | **Data** | **Source** | **Link** |
| 1 | Precipitation | USA.com | http://www.usa.com/rank/texas-state--average-precipitation--county-rank.htm |
| 2 | Distance from coast | Texas Department of Transportation (Txdot) for the boundary of Texas county map, then filtering was done using Arc GIS. | https://gis-txdot.opendata.arcgis.com/datasets/TXDOT::texas-county-boundaries-detailed/explore?location=31.059220%2C-100.077018%2C6.77 |
| 3 | Land Type/Land Use | MRLC (Multi-Resolution Land Characteristics Consortium | https://www.mrlc.gov/data?f%5B0%5D=category%3ALand%20Cover |
| 4 | Elevation | TexasCounties.net | https://www.texascounties.net/statistics/elevation.htm |
| 5 | Urban Impervious | MRLC (Multi-Resolution Land Characteristics Consortium | https://www.mrlc.gov/data?f%5B0%5D=category%3ALand%20Cover&f%5B1%5D=category%3AUrban%20Imperviousness |

The reference paper used for discussion includes:

6. Ghebreyesus, D., & Sharif, H. O. (2020). Spatio-temporal analysis of precipitation frequency in texas using high-resolution radar products. *Water*, *12*(5), 1378.

Contribution of each member.

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| **GROUP 4 PROJECT WORK-FLOW** | | | | | | | | | | | | | | | | | | |
| **PROJECT ACTIVITIES** | **PROJECT DAYS** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Data Collection & Analysis | |  | | | | | | | |  |  |  |  |  |  |  |  |  |
| AHP Pairwise Comparison to determine Criteria Weights | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| TOPSIS Ranking (R Studio Programming) | |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |
| ENTROPY Weighting and Ranking (R Studio Programming) | |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |
| Result Analysis & Discussion | |  |  |  |  |  |  |  |  |  |  |  |  | | | |  |  |
| Project Report | |  |  |  |  |  |  |  |  | | | | | | | | | |
| **GROUP MEMBERS PROJECT CONTRIBUTIONS** | | | | | | | | | | | | | | | | | | |
| Data Collection & Analysis | | Precipitation Data | | | | | | | | Minhajul Abedin Tajik | | | | | | | | |
| Distance from Coast Data | | | | | | | | Kushum K C | | | | | | | | |
| County Average Elevation | | | | | | | | Deseyi John | | | | | | | | |
| Land Cover (wet land) | | | | | | | | Mason Wyche, Kushum K C | | | | | | | | |
| Urban Imperviousness | | | | | | | | Mason Wyche, Kushum K C | | | | | | | | |
| AHP Pairwise Comparison to determine Criteria Weights | | Excel Spread Sheet | | | | | | | | Mason Wyche | | | | | | | | |
| TOPSIS Ranking (R Studio Programming) | | R Studio | | | | | | | | Deseyi john | | | | | | | | |
| ENTROPY Weighting and Ranking (R Studio Programming) | | R Studio | | | | | | | | Kushum K C | | | | | | | | |
| Result Analysis & Discussion | | Group Discussion | | | | | | | | Deseyi, Kushum, Mason, Minhajul | | | | | | | | |
| Project Report | | Background of Study (Introduction) | | | | | | | | Deseyi John | | | | | | | | |
| Methodology | | | | | | | | Mason, Minhajul | | | | | | | | |
| Result Analysis & Discussion | | | | | | | | Kushum K C | | | | | | | | |